Investigating the impact of Collaborative Annotation on Student Quality of Learning in Higher Education

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Abstract
Collaborative Annotation is 'a literacy strategy that engages students in critical reading, critical thinking, writing and collaboration all in one activity' (Schwane, 2015). This study reports on the effect and role that a Collaborative Annotation tool we developed plays in the assessment of students' understanding of their course material and recommends the best pedagogical approaches and research possibilities that can further improve its impact on traditional learning contexts in the future. Our preliminary investigations suggest that there is a positive correlation of Collaborative Annotation using our tool with student quality of learning. This is promising as it is broadly in line with published research and indicates that our research merits further investigation on extending our pipelines to incorporate AI peers and assess how they impact students' learning.

Keywords
Collaborative Annotation; Active Learning; Online Assessment; Online Collaborative Learning; Assessment As/Of/For Learning.

Introduction

Collaboration is an active learning technique which allows students to develop novel ideas in isolation, bring them to a group context and discuss these ideas with peers who may have different viewpoints. The Collaborative Annotation (CA) process enhances this approach by allowing for ideas to be discussed directly within the material, keeping track of all ideas made as annotations and discussing which annotation may be considered as more correct. As students read each other's annotations and provide feedback, they are encouraged to critically think about their understanding of the material come to a more nuanced understanding.

Razon's (2012) findings suggest CA results in an increased learning comprehension amongst students, meaning they do not just memorise the material but internalise and understand its concepts. Research also reveals that students' soft skills significantly increase with this methodology, which can lead to improved future job prospects (England, 2020). However, this is only one metric to analyse this approach. There is little existing research around the pedagogical strategies to integrate this methodology into traditional learning contexts. Kalir (2020) believes that a read, remark, remix (RRR) approach should be taken to integration. We believe RRR to be promising, though it requires further development to articulate the precise practical steps needed for integration. We are informed by this existing literature which will guide us in setting the scene for an extensive study on the potential of our Collaborative Annotation tool and our several pipelines with modern technologies.

Generally, the impact Collaborative Annotation has on a students' learning experience is agreed upon. Most research suggests a positive correlation in using the Collaborative Annotation method (Novak, 2012). However, there are further aspects of this technique that may need to be considered. For example, the introduction of Artificial Intelligence technologies may offer students and teachers new

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options when it comes to learning in group settings such as students engaging with the AI to ask for personalised feedback and notes for their studies.

The primary research question for this paper is whether our Collaborative Annotation tool improves student's quality of learning? This has a broad scope as quality can be attributed to many metrics, for this study we will consider it as the average between the students' learning comprehension quiz, the groups' assignment result and the ASPECT questionnaire. These have been chosen because learning comprehension quizzes are a good indicator for students' retention of material in the classroom (Kalir, 2020), group assignments can assess the impact of collaboration in the assignment and ASPECT can measure the student's opinion on learning and enjoyment of it (Wiggins, 2017).

The remainder of this work-in-progress paper will look at how Maynooth University (MU) has implemented Collaborative Annotation software and how this may be integrated into traditional learning contexts. We introduce our concept of assessment pipelines which are pedagogical strategies for integrating CA software into existing learning contexts. We discuss the results gathered from our preliminary (UI/UX) testing, our initial experiment in a Software Engineering classroom and what these results mean for expanding our research into pipelines and modern technologies in the Collaborative Annotation process. Finally, we outline future work, such as how the MU software can be updated to accommodate more learning contexts, what new pipelines may be introduced, and importantly, the impact our Collaborative Annotation tool has on student quality of learning.

Software Implementation

Maynooth University has developed a Collaboration Annotation software which teachers can use to assess the understanding students have of their material. This software was developed as an online, full-stack JavaScript application with a MongoDB and Nest.js backend. Currently, students may annotate any type of PDF document, which can be seen in Figure 1. and Figure 2, providing annotation functionality for many disciplines. With this selection of features, we can investigate how these specific tools affect student learning, how our Collaboration Annotation tool can be used in various contexts and what changes need to be made to enhance student learning.

There are three categories of users in this software: administrators, teachers, and students. Administrators can control and assign accounts amongst students and teachers. Teachers can assign students material and organize them into groups, also annotating the documents they assign. Students can access these documents to create both personal and collaborative annotations on various materials. Our existing interface has been verified by extensive UI/UX testing using a small sample of students, where each was assigned to a user story and their feedback was assessed using a questionnaire. Teacher testing was also conducted.

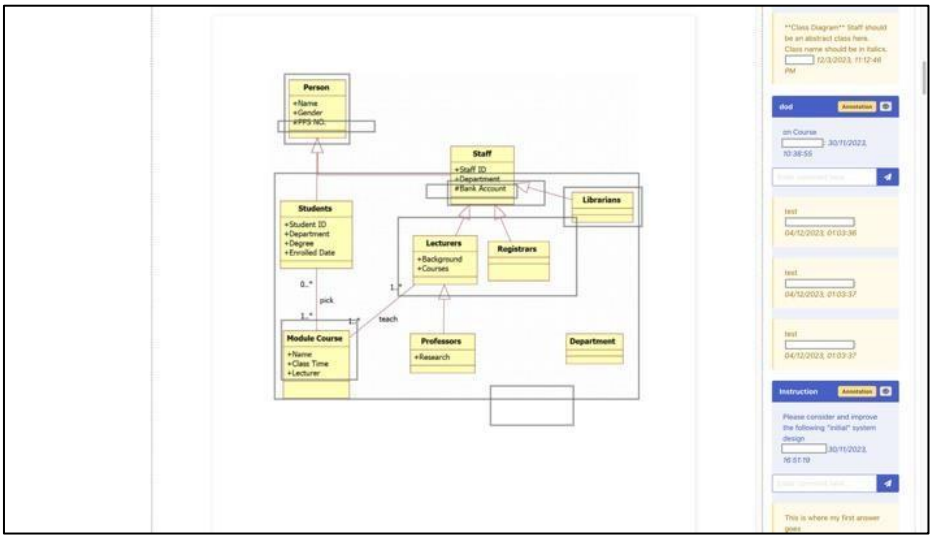

Figure 1. MU Collaborative Annotation software with annotations.

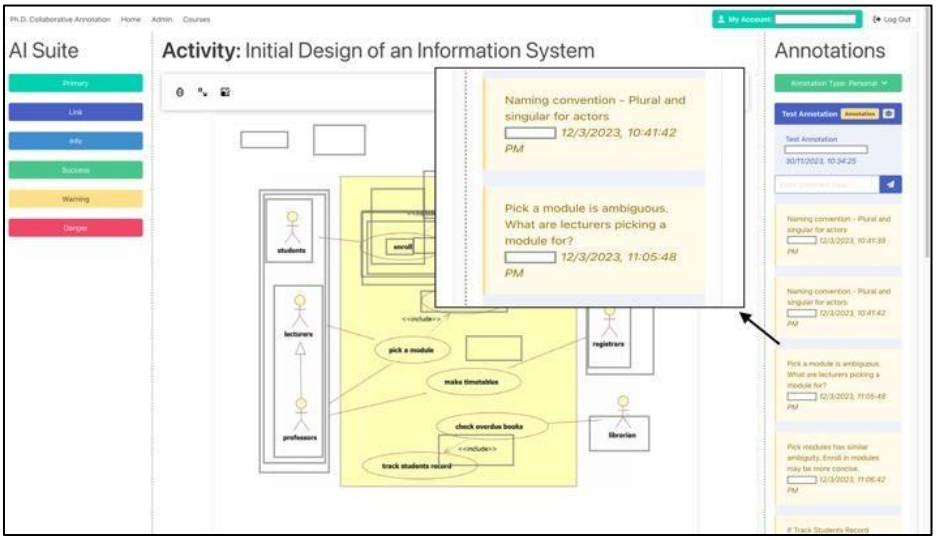

Figure 2: MU Collaborative Annotation software with comments.

The MU Collaborative Annotation software allows for conducting several forms of assessment describe later in this paper. The software allows teachers to upload traditional course materials to their students for annotation. Once the students have had a dialogue and submitted their annotations, the teacher may then review the assignment. During the review process they can grade and provide feedback to each individual student or to student groups (teams).

From the students' perspective, they are provided with the assignment artifacts (currently images and/or text) which are available for annotating as part of a team. Once complete, the group will asynchronously discuss their annotations and re-annotate to align with their new viewpoint after the dialogic conversations. The group, could for example, collectively decide which annotations are to be submitted for a group assignment, while the rest may be discarded. Once submitted and assessed by the teacher, students can view their grade and feedback to understand where they can improve performance in future assignments. Other collaborative annotation scenarios are possible; some of which are described in a later in this paper.

Two popular and excellent existing collaborative annotation software tools are *Hypothes.is* and *NowComment*. Each of these allow for users to select a document and make annotations, which may be for text, video, and image annotation. However, our software differs in several key areas. Firstly, our software is designed with modern technologies in mind, where we have considered our future research with Artificial Intelligence technologies in the functionality of our software such that we can incorporate AI as peers to help provide feedback to students and answer their queries. This gives our software more potential as it means we can research the role of AI in the classroom in future studies. Secondly, we have selected a modern design framework that supports mobile devices such that we can allow for our tool to work on tablets and phones in future versions. The minimal design also allows for students to easily make annotations faster.

Collaborative Annotation, as utilised in our software, may be considered *assessment as*, *assessment of* and *assessment for* learning. In this context, *assessment as* learning is the dialogue between students where actionable advice is exchanged, and self/peer review of the groups work is performed to reach a designated criteria constructed by the teacher. With *assessment of* learning, the teacher provides a final grade based on the students work and may choose to add feedback to specific annotations. The process of reviewing other annotations and critically analysing their own work is our *assessment for* learning criteria. The following sections address how our collaborative annotation tools' process works and how we intend to conduct our research study.

Collaborative Annotation Methodology

Quality in our study refers to the average result of the students learning comprehension quiz, their group assessment performance and the opinion students have towards their learning experience with its correlation to results achieved in assignments throughout the year. Collaborative Annotation impacts quality of learning in several important ways. Collaboration encourages critical thinking of a concept by the individual student before discourse of the material begins within the group, hence students will create their own understanding of the concept.

Furthermore, research into the zone of proximal development (ZPD) shows that students can understand only a given amount about a topic until provided with help by a knowledgeable peer or teacher. We believe that assessment utilizing Collaborative Annotation is an excellent approach that allows students to work in this zone and improve what they can do in future iterations of annotation as indicated by our findings in Figure 7.

We have analysed how to introduce Collaborative Annotation into existing pedagogical contexts. To achieve this, two adaptations must be made to assessment. First, documents that students review should be done along with other class-members such that everyone can provide their thoughts on the matter. This means that as a student, they should have access to documents and our Collaborative Annotation software so they can add their own notes and share them with peers and their teacher. Secondly, after the first iteration of annotation is done, the teacher must allow for time-spent for students to analyse their feedback and use it to improve their previous knowledge and notes.

For students working on the assessment, collaboration introduces them to new perspectives from the teacher and their peers, from which they can naturally link new ideas to their previous conception, developing a deeper understanding of a concept. The students begin by creating personal annotations on the document to formalize their understanding. From here, a dialogue is had amongst the group where new annotations may be generated. All of these are finally collected by the teacher who provides feedback as annotations for the students to review.

Given the example of an assessment in English poetry, students may have one interpretation of a verse, and after creating annotations can discuss with their peers what their interpretation was, allowing for disagreement and discourse all of which is valuable to the learning process. The teacher can comment on the work with additional information which the student can use to enhance their understanding of the literary piece. This process can be seen in pipeline one of Figure 3. Annotation is a form of notetaking, and the ability to weave notes into the document is much easier for students to understand, utilize and learn from rather than having to cross-check against many notes.

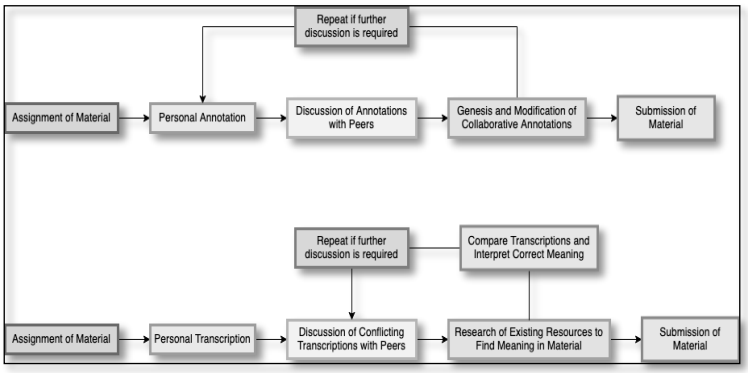

Figure 3. Collaborative Annotation Pipelines for Text Documents and Transcription Materials.

Figure 3. shows an additional two pipelines currently available within our Collaborative Annotation assessment manager. The first describes how text documents would be annotated by a student, having time to add personal notes, discuss and compare them with peers and generate/modify new annotations from these discussions. The second pipeline looks at language-based classes, with specific sections around discussing conflicting meanings when transcribing information.

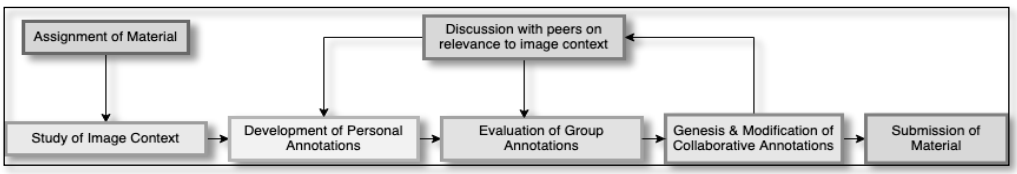

Figure 4. Collaborative Annotation Pipelines for Image and Video Materials.

Figure 4. shows the pipeline used for image and video annotation. The discussion phase has been moved to the top as after dialogic learning takes place, it makes sense for the students to revisit their own annotations as seen before, but also perhaps to review their peers again with new knowledge.

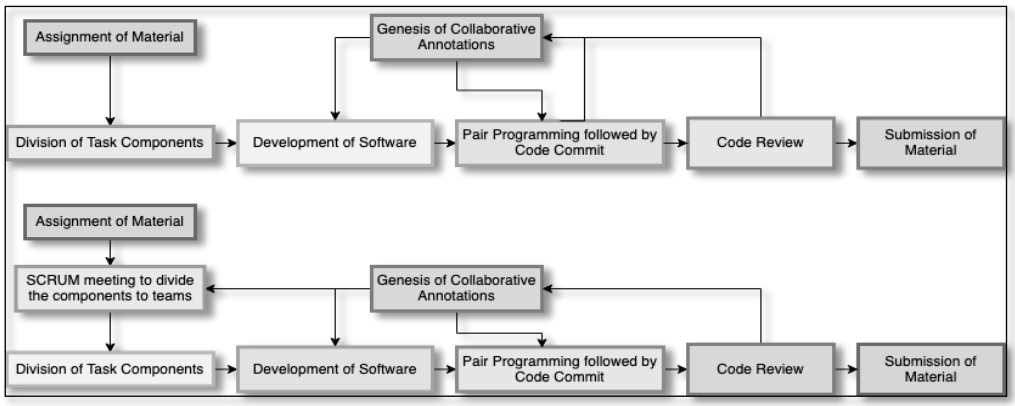

Figure 5. Collaborative Annotation Pipelines for Programming Tasks for Small and Large Teams.

Figure 5. shows pipelines for coding activities, which takes some elements from Agile Team Methodologies. As can be seen, from the pipeline, a pair-programming approach is favoured, where two students work together to generate annotations. Once complete, the code is reviewed by the teacher and feedback is given, from which they can learn and improve their work. This is an example of our *assessment for* learning, whereby the teacher gives the students feedback from which they can learn to improve for the next task. This generation and modification of ideas is *assessment as* learning, whereby students critically analysing their peers' work encourages them to develop new ideas regarding their own.

The remaining sections address our plans for an extensive research study and discuss what our preliminary findings mean for the future of our research. Each of these pipelines implements the assessment as, assessment of and assessment for learning methods that we have outlined in above despite their different contexts, which are all available within the MU Collaborative Annotation software with consideration for modern technologies.

The Research Study

As shown in the previous sections, we have comprehensive software that allows for a wide range of assessment. Assessment of progress with our Collaborative Annotation tool and its impact on students is the most crucial aspect of this study. Students will be assessed by three metrics; Firstly, students will be assessed with a learning comprehension quiz to see if they understood and internalised the concepts that were being discussed. Next, we will assess how the social factor of this active learning technique affected students' learning quality. We will use the ASPECT questionnaire devised by Higgins' for this process. Finally, we will take the group assessment performance analysed by the teacher to assess students' work in class.

Feedback forms will be our main form of qualitative feedback in this study. These will allow us to ask students questions about their experience with the software, what their general thoughts on our Collaborative Annotation tool and what improvements can be made. One part of this form will be Wiggins' (2017) ASPECT model, used to analyse students' opinions regarding social learning activities, such as collaboration. Further questions will ask students for recommendations they may have in improving the software.

We will also ask context-specific questions such as how students found text annotation as opposed to image annotation, as well as what they saw as useful and what could be improved. Finally, we will use SAPA and PAF as described by the University of Queensland (2018) as metrics to analyse how well students participated in their groups. This is to understand the importance each piece of feedback has. From this, we can deduce which students engaged with the process effectively and what improvements can be made to help those who did not.

In this experiment, our approach uses materials provided by teachers in our chosen subjects (Irish Language/Literature, Geography, History). This allows us to focus on assessing only the software's impact and techniques effectiveness in a real class scenario, as it ensures the content is familiar to students and the teacher, removing the variable of seeing unfamiliar coursework from our analysis.

We will conduct our study with a set of three assessments across several subjects (History, Irish Language/Literature, Geography). Each assignment will be designed in conjunction with their associated teacher specialists. These will be measured by the teacher grading each assignment at the end of the experiment. In our study, we consider literature subjects to typically be text-based, whereas subjects such as History and Geography have aspects of text and image, therefore we will split them accordingly to report on the success of each annotation form.

Irish Language/Literature can be conducted as a solely text-based activity, Geography as a solely image-based activity, and History will be a mix of both. This is to give a variety to the learning contexts we explore. We will discuss with the teachers what assignments might be best suited for these conditions as they will have the area-expertise needed to develop the assignments. These sessions will run twice a week for three weeks, each week covering one of the topics mentioned above. Ideally, we would want to work with a group of 20 students a week to have 5 groups of 4. An even mix of year groups would also be perfect to ensure we get data from each section.

We will also conduct a summative assessment in the form of group assessment performance to explore and compare whether students have a better understanding of the course material following assessment utilising collaborative annotation.

We will design a questionnaire for those who used the Collaborative Annotation software to get their thoughts on the tool/methodology itself, as well as a questionnaire for those who did not use it. This latter questionnaire is to identify what the groups would have benefitted from using during their exercise. Beginning the experiment, the class will be provided with a brief instruction on how to use the Collaborative Annotation software, along with the details needed for them to login to their account. Once this tutorial ends, we begin the experiment.

The class groups will begin by being given a small task to complete first to get familiar with the software. From here, they will proceed to complete their groups assigned tasks tailored to one of the study topics (Irish Language/Literature, History or Geography). This will allow us to assess a handful of pipelines we have designed for different learning contexts. We will ensure that teachers and teaching assistants are also made aware of how the software works in a session prior to conducting the experiment. Students as mentioned above will be assessed in three ways. Firstly, the grade of the assignment in question will be calculated by the teacher in that subject to get an overall benchmark to compare students who used our software with those who have not. This can be used to gauge the effectiveness our Collaborative Annotation tool has on learning activities. Secondly, the group assessment performance will be used to analyse how well students learned the material that they worked on in their learning context. Thirdly, the questionnaire will be used for us to make improvements in the collaborative annotation learning process and pipelines in the future.

Results

We have conducted our first research study (experiment) using a class of MSc Software Engineering students (n=21) studying a module entitled ‘Requirements Engineering & System Design’. We began our experiment by providing students with a sample collaborative annotation training assignment which required them to collaboratively annotate a research paper and respond to each other’s annotation using comments. This was used to introduce them to the concept of group-based Collaborative Annotation Assignments and how they are accomplished using the software tool. Students learned about the concept of an assessment timeline (pipeline).

The following step involves collaborating with the module lecturer to design a collaborative annotation assignment of an authentic assessment typically given as part of the module. It was decided to use a UML diagram as the assessment boundary object and students would be required to (i) identify software design patterns in the diagram, and (ii) identify design mistakes. This assessment was worth 5% of a student’s summative grade. The students were tasked with first creating individual, or solo, annotations on the document and responding to the lecturer’s question, also represented as document annotation, with their initial answers. Then, they were exposed to small group annotations, and were tasked with reviewing their groups annotations and provide feedback/comments on each of their

group members' annotations. Finally, they would provide an updated answer to the lecturer's annotation following the insight provided by peers, together with additional knowledge they gained from dialogic engagement with their peers.

Q1: Explaining my material to my group improved my understanding of it.
Q2: Having the material explained to me by my group members improved my understanding of the material.
Q3: Group discussion during the Collaborative Annotation contributed to my understanding of the material.
Q4: I had fun during the Collaborative Annotation.
Q5: Overall, the other members of my group made valuable contributions during the Collaborative Annotation.
Q6: I would prefer to take a class that uses Collaborative Annotation rather than one that doesn't.
Q7: I am confident in my understanding of the material in the Collaborative Annotation activity today.
Q8: Collaborative Annotation improved my understanding of the material.
Q9: Collaborative Annotation stimulated my interest in the course material.
Q10: I made a valuable contribution in the Collaborative Annotation activity today.
Q11: I was focused while using Collaborative Annotation.
Q12: I worked hard while using Collaborative Annotation.

Figure 6. Modified ASPECT Questionnaire, where students stated how much they agreed with the statement on a scale of 1-10.

We collected positive feedback from the lecturer and students participating in the trail study. We gathered results from our modified ASPECT questionnaire (shown in Figure 6.), where students reported that they had a better understanding of the subject matter by using Collaborative Annotation, as well as being more interested in the subject matter (UML Design) itself (as can be seen in Figure 7.). Furthermore, students would prefer to participate in a classroom that used this technique rather than one that did not. Students also provided some feedback on the software system itself in our questionnaire, mostly regarding the user interface and. This is unsurprising given that they were software engineering students. Most recommendations were very useful. Some feedback included refreshing the page immediately after uploading a comment and being able to filter the annotations more thoroughly.

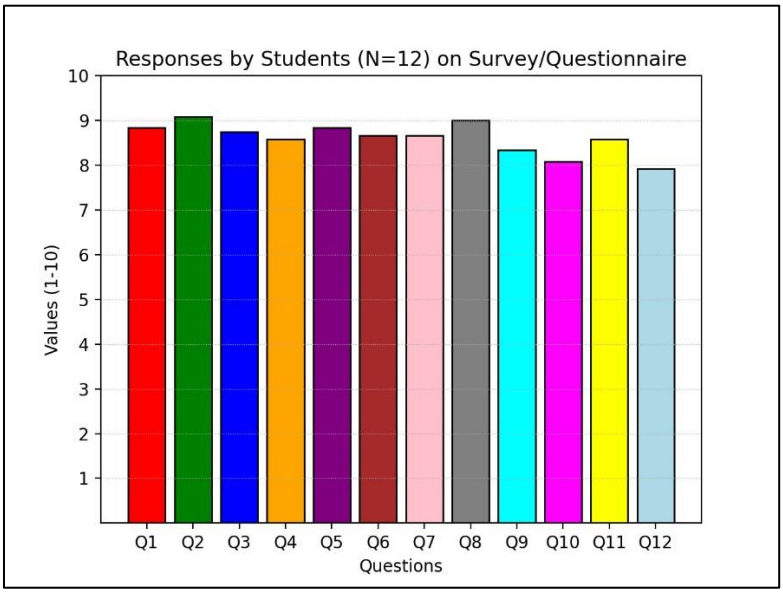

Figure 7. Average Responses to ASPECT Questionnaire (1=Disagree, 10=Agree).

We also collected data on the summative grade received from the lecturer as presented in Figure 8. We noted that of the 21 students in the class, only 8 made their own unique annotations. Given the low number of responses in this aspect of the analysis, we point to the study conducted by Razon (2012) on the impact of their Collaborative Annotation tool. They find with a larger sample size that there is in fact an increase in students' summative grades. From both our modified ASPECT questionnaire and the findings on summative grades mentioned above, we conclude that our tool for Collaborative Annotation impacts the students' quality of learning in a positive manner.

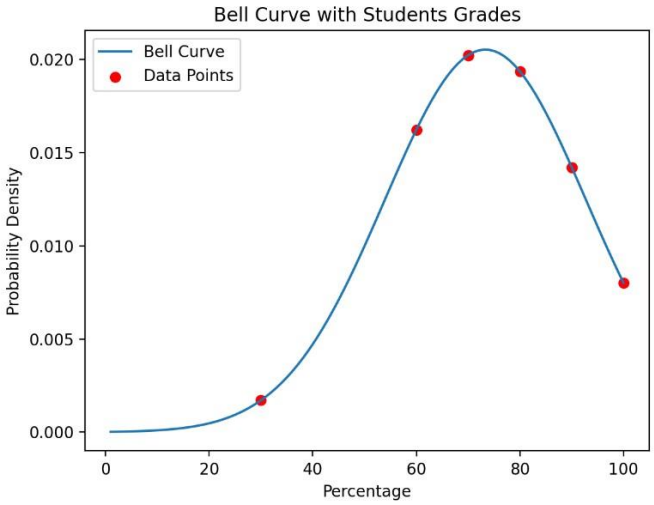

Figure 8. Results of Students Summative Grades.

Discussion

Although we our initial study indicates a positive impact for our Collaborative Annotation tool on student quality of learning, this is our initial experiment, and we would like to implement more of our defined requirements in future iterations. For example, we would like to work with a control group to compare how students who don't use our tool perform. Furthermore, we would like to conduct the Learning Comprehension Quiz after some time with our group to ensure students retain the material. Students also provided feedback to improvements in the software, such as colour-coded annotations for each user and having documentation for new users. These are areas we can expand in the future, and also reuse this feedback questionnaire for our AI-integration research.

As we plan to extend our pipelines beyond current research, we are looking at the role of Artificial Intelligence technologies such as ChatGPT and Llama-2 in supporting both students and teachers alike in our pipelines and tool. We believe that by providing these AI tools with artefacts such as the students' notes and the course material in question that they can receive feedback relevant to their work, get tailored answers to questions they may have regarding the material and provides teachers an insight into what queries students ask the AI such that they can update their practice to accommodate the students. We plan to investigate new pipelines that involve using these Large Language Model technologies acting as students and contributing their own annotations to the group and responding to student queries of the material. Furthermore, we are integrating evaluation tools for teachers to identify areas that students may be weak in such that they can adapt their pedagogical strategy to respond to students' requirements.

Kalir (2020) hypotheses that for Collaborative Annotation to be integrated in existing education conventions, it must follow a read, remark, remix (RRR) approach. In the remix stage, discourse amongst students is required but is not clear on how these groups would be constructed. We will further develop this strategy in our research to incorporate specific and practical tools and pedagogical

approaches to make it easy for teachers to integrate with their own pedagogy. Research from Akinola (2014) leads us to believe the ideal group size to be in the range of 3-5, though this may differ given the context of his study and our field. Our preliminary investigations as part of our UI/UX study show that there is a pattern to this, as too large group sizes may flood a document with similar or redundant notes, while a smaller group size may discover nothing novel or deepen understanding. We believe there should be criteria to group size and composition such that learning, and discussion are encouraged amongst all members which merits investigation.

Wolfe (2008) considers a pedagogical approach where having annotations of conflicting perspectives displayed alongside each other would prompt further discussion to generate annotations which may be more correct/relevant. Annotations should also be designed to support information retrieval as students appear to remember these better than the body of the text itself. We will implement these worthwhile features in our own collaborative annotation software and investigate its impact on student learning. We believe that student training in the art and science of Collaborative Assessment is important and is worth investigating. For example, if they are collaborating on a piece provided by their professor, it may be harder to understand how these annotations can be used to improve their work as it does not directly link to them without this understanding provided by training. We wish to investigate which pedagogical approach impacts students learning with our Collaborative Annotation tool most positively. To improve students' quality of feedback, we believe teachers should introduce students to the concept area and provide them the methodologies to make the most use of this software.

Summary & Future Work

Our preliminary findings suggest that there is a positive correlation between student quality of learning and the use of our collaborative annotation tool in their assignment. This means that further improvements in the pipeline and our tool can result in improved grades, group assessment performance and student attitude towards learning. Once ethical approval has been sought and views or comments from the community have been considered, we will proceed to use the methodology above to investigate our research question with more class groups. We will also continue to make improvements to the MU Collaborative Annotation software in supporting other pipelines not yet considered and in integrating the aforementioned tools such as Artificial Intelligence for use in the classroom.

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