PREPARING TEAMS OF NEURO-TYPICAL AND NEURO-ATYPICAL STUDENTS WITH A COMPUTER ORCHESTRATED GROUP LEARNING ENVIRONMENT FOR COLLABORATIVE WORK: A MULTI CASE STUDY

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Conference Key Areas: *Diversity and inclusiveness and E-learning*
Keywords: *Neurologically atypical, ASD, ADHD, Collaborative learning, Computer supported collaboration (CSCL) at computer*

ABSTRACT

The number of students entering higher education with a diagnosis of Autism or ADHD is on the rise, and within engineering it is higher than the sector average. This calls for understanding how these students experience higher education and how best to support them in overcoming socio-communication challenges and developing the teamwork skills required by industry. This article investigates a novel Computer Orchestrated Group Learning Environment (COGLE) that orchestrates content delivery and learning in small face-to-face groups of neuro-typical (NT) and neuro-atypical (NAT) engineering students. This research uses a literal replication logic, where multiple similar case studies contribute evidence towards analytical generalisation and transferability. COGLE is used in the first case in a flipped classroom setting and in the second case within a Project Based Learning setting. The teamwork skills of NT and NAT students were compared. Normalised learning gain (NLG) scores were computed using pre and post test data. Qualitative comments provide insights into the experience of NT and NAT students. Key lessons learnt highlight the importance of learning together to master content before engaging in collaborative activities such as peer instruction commonly within flipped classrooms and teamwork within Project Based Learning. In both case studies, NT and NAT students had comparable NLG scores and developed their team working skills. This research shows that both staff and students can benefit from COGLE as it prepares students for collaborative working by improving both technical knowledge and team working skills freeing up staff to focus on guiding and supporting student learning.

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1 INTRODUCTION

1.1 Increase in collaborative approaches within Engineering Education

Collaboration skills are considered important within most professions. In engineering, team working skills are considered as one of many crucial skills for the success of any real-world open-ended project. Higher engineering education curricula, in the UK and elsewhere, have seen recent changes in response to the calls from industry and professional bodies to increase focus on problem solving and team working and using collaborative approaches to develop these graduate skills [1-3,8-9]. Learning in groups within engineering has been shown to have greater achievement, with a moderate effect size (d=0.25), than learning individually [4]. As a result, collaborative approaches such as Flipped Classroom (FC) and Project Based Learning (PjBL) have gained popularity over the years within Engineering Education [5-6]. In FC, students are expected to prepare the content themselves and take part within collaborative active learning activities in class [5, 7]. In PjBL, students work collaboratively in a group, on a defined real-world project and are expected to learn what is needed to deliver the project. The popularity of such approaches has meant that there has been a shift in the expected role of the academics from being a 'sage on the stage' disseminating information to a more supporting 'guide on the side' role [6]. There are, however, many challenges that come with this shift in expectations and practice.

1.2 Challenges collaborative approaches bring to Engineering Education

Without theoretical knowledge that underpins the change in their role and the skills needed by staff in facilitating groups, staff often face challenges when adopting PjBL or FC approach [6-7]. Not just staff, the students also find it hard to develop and use interpersonal skills if they have not had and do not have access to any formal team skills training [6-7]. Furthermore, PjBL is resource intensive and requires more staff to facilitate teams and to put in extra effort in guiding students. This is particularly important where students are from multicultural backgrounds [6]. As PjBL needs more resources from schools or departments, it can lead to a reduction in institutional support for such approaches over time [6]. This puts any benefits of the PjBL approach, where realisable, at risk. Likewise, students find it time consuming and hard to prepare on their own in the FC approach. Due to limited student preparation, staff find it tricky to carry out their planned collaborative activities in a way that is fair and benefits the entire class [10]. In practice, staff often find themselves performing both the roles of teacher and facilitator, especially when students complain about not being able to learn or work on their own on open-ended real-world problems without being taught first and a similar criticism is faced for flipped classroom approach too [6,10].

More and more neurologically atypical students (NAT) are entering higher education as diagnosis rates are on the rise. NAT is an umbrella term that includes Attention Deficit Hyperactivity Disorder (ADHD) and Autistic Spectrum Disorder (ASD) students. Researchers have claimed that NAT students are more likely to study engineering and technology courses [11]. As a result, it is very likely that most engineering cohorts will have a mix of neurologically typical (NT) and neurologically atypical (NAT) students learning together. Formally diagnosed, or not, such students face socio-communication challenges that may affect them in realising their full potential [11]. Social interactions and communication are crucial for success within PjBL and FC activities, making it harder for NAT students to succeed. In addition, reasonable adjustments are needed by law and teaching NT and NAT students alongside each other poses problems [12]. In practice, the demands of PjBL and FC can put most students under pressure, including NT, diagnosed NAT and those that remain undiagnosed [13]. Therefore, the challenges faced in social interactions and communication within group work can limit the success of FC and PjBL for NT as well as NAT students.

1.3 Context and Rationale

Both FC and Project based learning are used within the School of Energy and Electronic Engineering at the University of Portsmouth. Here, teams of students may need to collaboratively design, build and test say a communication system as part of a PjBL project or collaboratively discuss design challenges related to electronic subsystems within FC activities. Disability data from Higher Education Statistics Agency (HESA) show 0.9% (male), 0.2% (female) & 3.6% (other) current UK domiciled students have ASD or other social communication disorder [24]. Research suggests females can be better at masking social behaviours common in NAT and are not being diagnosed as a result [22-23]. As NAT students are more likely to study engineering [11], supporting the already small % of female students entering engineering degrees becomes even more important. In the last three years alone there has been an increase in students with specific learning disabilities (including ADHD) and ASD to 15.7% and 1.2% respectively within the school. This increasing trend in NAT students joining our courses, combined with potential benefits to NT students from an intervention that can cater to both NT and NAT students learning together, provides the rationale for this study. COGLE may provide an approach to teaching that is inclusive for students with socio-communication challenges and enhancing their learning and team working experience.

2 METHODOLOGY

2.1 The intervention: Computer Orchestrated Group Learning Environment (COGLE)

COGLE was developed within the School of Energy and Electronic Engineering at the University of Portsmouth. It orchestrates small face-to-face groups of students watching together short videos followed by orchestrating them practice related questions till they all achieve group-wide mastery, i.e. they can all show that they understand the content by answering questions. During each session students are paired several times to carry out peer instruction with those who get the questions wrong. COGLE runs within a web browser with videos hosted anywhere on the web, for example YouTube®. The questions are carefully designed to encourage discussions between students. To achieve group-wide mastery all students in a team have to get 10 questions correct in a row. Anyone making a mistake resets this target and they must start again. COGLE is able to identify mistakes that are prevalent within the group, thanks to the careful question design. It plays a remedial video based on the most prevalent mistake in the group.

2.2 Underpinning pedagogical theories

Peer Instruction is widely used within higher education to help students learn from each other in real-time environments [14-15]. The COGLE platform automates the grouping of learners needed in PI in a democratic and inclusive way. This gives a chance to all students, including NAT students, to engage in peer learning. It is hoped that mastery of content [16-17], when extended in a group-wide sense ensures a higher learning gain for learners in groups for both NT and NAT students alike. The repeated orchestrations have the potential to aid the internalisation of team working skill, as predicted by the *Script guidance theory* [18].

2.3 Research site, participants and research design

Two Electronic Engineering modules, one at level 3 (first year of foundation degree) and one at level 4 (first year of undergraduate degree), were chosen where FC and PjBL activities were being used respectively. This formed the basis for students from level 3 to use COGLE to prepare for FC activity and level 4 students to prepare for PjBL task. The module co-ordinator confirmed observing similar challenges as noted above in both the modules. The two modules also benefit from covering the same basic material in the early parts of the course to ensure students are introduced to basics of electronics before moving on to advanced topics in level 4 module. In order to investigate the potential of COGLE in supporting NT and NAT students together within a real-world setting participants were invited from these two modules to join the study.

The study was approved by the University's research ethics committee and students from the two cohorts were invited to come forward, in particular those with ASD and ADHD, and give informed consent for taking part in this study. This was the only way we were allowed to reach out and recruit students and as no access to entire cohort was permitted by the ethics committee. A total of 19 students joined the study, 9 from level 3 foundation course in Engineering and Technology and 10 from the BEng Electronic Engineering course. Three foundation students did not complete and left the study mid-way as one of their teammates, an international student, went back without giving any explanation leaving a group of 2 who did not wish to continue. The remaining 6 level 3 students were put in teams of 3 each randomly and were put into the FC case-study of the study. One level 3 student self-declared themselves as autistic. The remaining 10 level 4 students joined the PjBL case-study and were put in random teams of 3 or 4 students. In level 4 one student was diagnosed as Autism (comorbid with ADHD) and one student had ADHD. All 16 students completed the study.

Students on the FC case-study learned together for 4 two hrs sessions in their designated teams prior attempting a two hour FC collaborative design challenge in their designated teams. Students on the PjBL case-study, did the same 4 two hour sessions and in addition 3 further two hour sessions (7 sessions in total) to master the content needed for the PjBL task in their designated teams. The FC task involved designing a bass and treble filter circuit to be used as input to a head-phone amplifier. The PjBL task was more complex where the students were required to design both the filter circuits as well as the headphone amplifier within the same two hour time. The content used in the FC case-study was also used in the PjBL case-study in addition to more content on advanced topics as needed for the PjBL project. The two case-studies thus formed part of a literal replication multi-case study design used here [19]. The use of orchestrated group-wide mastery in two different case-studies should generate robust evidence advocating for using such an approach with NT and NAT students within Engineering Education settings to enhance their knowledge and internalising team working scripts used within COGLE.

2.4 Methodology for evaluation

One of the challenges reported above within FC and PjBL contexts is to do with students finding it hard and time consuming to prepare content before taking part in the collaborative activities. If students have mastered content using COGLE and they understand the concepts needed within the collaborative activities, they are more likely to feel able to contribute to the FC and PjBL activities and complete the tasks set within each. The automated nature of COGLE solves this and the resource intense issue in PjBL, but to prove that this intervention can actually teach in an efficient way, this research uses a pre post-test designed in the two cases presented. A test comprising questions similar to the ones used within COGLE, but without the multiple options, was used to measure the students' knowledge before and after the COGLE sessions and before going into the FC or PjBL activity. Normalised learning gain was computed using the formula stated in *Eq. (1)* using the pre and the post test scores of each student in the study.

$$Normalised\ Learning\ gain = \frac{Posttest - Pretest}{100 - Pretest} \qquad (1).$$

Appropriate statistical methods like t-test and effect size are calculated as the data collected was normally distributed to test the null hypothesis as follows:

H_0 - There is no statistically significant difference between a student's learning gain before and after the use of COGLE.

It is also predicted that the learning gains of NT and NAT students will be comparable. As the number of NAT students was really small, hypothesis testing cannot be used here for this prediction.

Another area where COGLE plays a role is the development of team working skills of the students. After each session the students were asked to complete a survey with free text space to answer the following questions.

1. Describe what did and did not go well, when prompted by the system, to teach or explain to other student(s) a concept.
   a. Also, describe how the system made you or others in your team contributed to improving or worsening the situations you described as “did" or "did not go well” above respectively.
2. Describe what did and did not go well, when prompted by the system, to learn from other student(s), a concept.
   a. Also, describe how the system made you or others in your team contributed to improving or worsening the situations you described as “did" or "did not go well” above respectively.

In addition, qualitative data was collected through an hour long interview. The interviews were transcribed verbatim by professional transcriber. This paper only presents initial analysis of the quantitative data and present some key themes from the qualitative data from the daily survey that was analysed using grounded theory inspired thematic analysis [20]. The analysis is still underway and will be presented in a subsequent research article.

3 RESULTS

3.1 FC Case

As there were only 6 students in this case, a test for normal distribution was conducted before any statistical methods were used to analyse the results. Table 1 shows the raw data along with the normalised learning gains (NLG) for each student. All students including the autistic student have large positive NLG values.

Table 1. Raw scores and Normalised learning gains in the FC case

Student	Pre-test %	Post-test %	Normalised Learning Gain	NT/NAT
A0	*0*	*43.48*	*0.43*	NAT
A1	*43.48*	*60.87*	*0.31*	NT
A2	*43.48*	*73.91*	*0.54*	NT
A3	*17.39*	*60.87*	*0.53*	NT
A4	*17.39*	*30.43*	*0.16*	NT
A5	*34.78*	*82.61*	*0.73*	NT

The Kolmogorov-Smirnov test of normality was performed on the pre and the post test data. The p-value was 0.89036 (>0.05) for the post test score and p-value for the pre-test was 0.91253 (>0.05). This means that the data does not differ significantly from that which is normally distributed and therefore *t-test* was carried out with a *t value* =

5.416328 and a p-value=0.0029, meaning the result is significant (p<0.001) and we can safely reject the null hypothesis here. This equates to a large and significant effect size of 1.7803 with confidence interval CI (0.43, 3.11).

The results indicate that all students were able to learn using COGLE. The lowest value of NLG was 0.16 and the maximum was 0.73. The autistic student, A0, has a NLG of 0.43. The ASD student’s score is comparable to other NLGs measured here, indicating that NT and NAT students experienced similar benefits from using COGLE. Within their team, which consisted of student A0, A1 and A2, the NLG of the ASD student is comparable to the range of scores achieved by this team. These results indicate that all students were able to learn using COGLE efficiently without the needs of facilitating staff.

3.2 PjBL case

As there were only 10 students in this case, a test for normal distribution was conducted before any statistical methods were used to analyse the results. Table 2 shows the raw data along with the normalised learning gains (NLG) for each student in this case. All students including the autistic and the ADHD student have large positive NLG values.

Table 2. Raw scores and Normalised learning gains in the PjBL case

Student	Pretest %	Posttest %	Normalised Learning Gain	NT/NAT
A0	26.47	85.29	0.80	NT
A1	23.53	44.12	0.27	NT
A2	35.29	70.59	0.55	NT
A3	29.41	52.94	0.33	NT
A4	14.71	55.88	0.48	NT
A5	26.47	55.88	0.40	NT
A6	35.29	61.76	0.41	NT
A7	26.47	55.88	0.40	NAT
A8	35.29	73.53	0.59	NAT
A9	38.24	70.59	0.52	NT

The Kolmogorov-Smirnov test of normality was performed on the pre and the post test data. The p-value was 0.63674 (>0.05) for the post test score and p-value for the pre-test was 0.64631 (>0.05). This means that the data does not differ significantly from that which is normally distributed and therefore *t-test* was carried out with a *t value = 9.697417* and a p-value=0.00001, meaning the result is significant

($p<0.0001$) and we can safely reject the null hypothesis here. This equates to a large and significant effect size of 3.369 with confidence interval CI (2.00, 4.724).

The results indicates, all students were able to learn the basics as well as more advanced topics in electronic engineering using COGLE. The lowest value of NLG was 0.27 and the maximum was 0.80. The autistic student, A7, has a NLG of 0.40 and the ADHD student, A8, has a NLG of 0.59. Both are within the range of NLGs measured here, indicating that NT and NAT students experienced similar benefits from using COGLE. Moreover, Team 3 consisted of student A6, A7, A8 and A9. The NLG of A7 is at the lower end of the range of scores achieved by this team. A8 seems to have benefited greatly by using COGLE, more so than other students. Both scores are still close to each other and comparable to other NT students in the study. Much like the previous case, the results here too indicate that all students were able to learn the basics as well as more advanced topics in electronic engineering using COGLE efficiently without the need of facilitating staff.

The daily survey data was focussed on each session during the learning together phase in both case-studies. The data was coded line by line using inductive coding, codes were then analysed to identify themes and sub themes within the data. *Mastering the content together* with several orchestrated interactions and support provided by COGLE encouraged students to overcome initial *social awkwardness* and *improve their connections with each other.* This way they *learned better together* as shown in the learning gain data above. The many interactions orchestrated by COGLE and those that were self-orchestrated *brought the teammates together*, preparing them for teamwork that was to follow. COGLE also helped *arbitrate conflicts* by pairing the relevant peers for discussion and supporting their discussion with *correct answers* and *remedial videos*. Practicing group-wide mastery in this way meant they *internalised* the approach of discussing topics with each other with an open mind and used it during the un-orchestrated FC and PjBL task activity. A sample of qualitative comments from NAT student show how COGLE helped the NAT students *master the content together* and *prepare for the team work* that followed as shown by free text comments from the daily survey that captured key events that took place in each session:

- "...*worked together as a team to master* the questions...both team mates explained a concept, *each one did it differently* so *helped* with *improving my knowledge*" (ASD student, Level 3)
- "It allowed us to *discuss with each other* how to *get the correct answer* and as such allowing us to cooperate better due to *our improved connections with each other*" (ASD student, Level 4)
- "It was useful in *highlighting* simple *errors we had made* individually and *helped us to understand the material*" (ADHD student, Level 4)

The student with ADHD benefitted by an enhanced understanding of the topics, in particular as COGLE highlighted the small mistakes he made, as he was prone to, due to his disorder. The ASD student felt that they were able to connect better with others in using COGLE.

The NT students had similar experience too as shown below:

- "The system made it clear as to what was wrong and right giving a percentage of who answered it correctly and incorrectly. *It stopped arguments* this way as the answer was projected to the whole group and the *participants who got it right were allowed to explain it* to the rest of the group." (NT teammate of ASD student, Level 3)
- "The *system recommended that we not only discuss with our group mates*, but watch a *video* which was related to the problems we were getting stuck on. This really helped in the long run and *helped us finally achieve mastery*." (NT student, Level 4)
- "It [COGLE] *helped us to work as a team* to get *all the questions* right." (NT student, Level 4)
- "we were *all* able to say our ideas to each other and we made sure we *were all on the same page* and if we didn't get it still *we were able to watch a video and discuss with each other* about the video to make sure *we all understood* this really *helped when the style of questions* were repeated because we then knew how to solve the questions" (NT teammate of a NAT student, Level 4)

The NT students also benefitted by an enhanced understanding of the topics, in particular as COGLE supported them with remedial videos and by promoting the exchange of diverse views between all students repeatedly. The NT student felt that they were able to connect better with others in using COGLE as it helped arbitrate conflicts and invited all students to have their say. The quotes above and the quantitative data presented earlier both point towards the successful teaching and learning that took place within COGLE in the two cases. It also shows that NT and NAT students found the support provided beneficial for learning and team working.

4 Discussion and implications for engineering educators

The two cases provide repeating results adding strength to the claim that COGLE is able to support a mix of NT and NAT students where both acquire domain knowledge and team working skills. Having mastered the content needed for the FC or PjBL tasks, through learning together in COGLE, COGLE enhances self-efficacy and develops the skills needed by the students for team working. They arrived ready as a team to work on collaborative tasks set for them and all teams completed their set tasks with scores over 70%.

The benefit of COGLE is not just for students, staff can benefit too. After a one off investment in time in creating video content and questions, COGLE can be deployed any number of times and for any number of teams within the limits of the physical space within the school. COGLE can be used over distance too but this was not studied in this research. Using COGLE for FC preparation changes what may be commonly understood as the Flipped Classroom approach. Here, instead of expecting students to learn individually at home, students can be programmed to come in for preparatory sessions, where minimal supervision and no teaching is actually needed as this is orchestrated by COGLE instead of an academic. We call these sessions as software assisted learning together sessions. During the FC activity, academics orchestrate collaborative active learning tasks, such as peer instruction, based on the content already mastered within COGLE sessions. Likewise, for PjBL the students can learn together with minimal resources before attending their PjBL lab sessions and team meetings. In both cases, the time with the academics can be more meaningful as the class and the groups are already prepared for collaborative tasks and projects.

5 SUMMARY AND ACKNOWLEDGEMENTS

This work presented the evaluation of student performance and team working in collaborative settings such as FC and PjBL after using a novel group learning environment, COGLE. It shows how both NT and NAT students were able to master content and come together as a team as they prepared for collaborative activities. They also completed the FC and PjBL activity that followed successfully. This means that COGLE was able to support NAT students in overcoming socio-communication challenges in an inclusive manner whilst learning alongside NT students. Staff can also benefit from the use of COGLE as it frees them from having to teach instead of focussing on guiding and student needs. COGLE prepares students before they set foot on collaborative tasks that require both team working skills and mastery of technical knowledge, the two most important pillars in engineering education. The effect size is greater than other studies involving learning in teams [4]. The learning gain results are generalisable to the population as shown by the rejection of the null hypothesis for the two cases. The two cases show the transferability of the intervention design for mixed groups of NT and NAT students in terms of the team working skills and other themes in the qualitative comments. Likewise, comparing results from COGLE based case-study with traditional environments or student orchestrated groups will enhance the claims made in this study with regards team working skills. During the search for studies involving team working skills development of NT and NAT student together, none were found. Multiple studies involving larger cohort size and in different engineering disciplines can help with the transferability of the results further.

This work benefited from the dean’s fund for supporting research within the school. The authors are grateful for the continued support for this project as we investigate further collaborative learning within engineering education with bigger cohort size in order to help with the transferability of the results further. The authors are also grateful to the anonymous reviewer comments received in the preparation of this work.

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