Analysis of Student Preference to Group Work Assessment in Cybersecurity Courses

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Abstract

This study explores the impact of taking a diverse and inclusive approach to designing a group work assessment for an undergraduate cybersecurity course delivered to third year university cohorts. Students were given the choice to either work individually or as part of a group of their preferred size to complete a cybersecurity-based assignment in virtual labs. Student preferences were employed to evaluate the impact of grouping preference upon academic performance. The analysis demonstrated that variations in teaching structure in relation to the Covid pandemics has had an impact on student grouping preferences. Students also revealed that personal preference, academic confidence, peer learning, workload sharing, flexibility and efficiency are popular rationale for their grouping preferences, establishing their personalised learning style and journey.

Keywords

group work, grouping preference, assessment, academic performance, correlation, one-way ANOVA, cybersecurity, diversity and inclusion, virtual labs, personalised learning

1. Introduction

Group work has been a popular choice in cybersecurity education with teamwork an essential approach to developing solutions, to problems in the cybersecurity industry. From an educational perspective, a recent literature review published in 2020, on cybersecurity education [1] found that exactly half of the 64 teaching papers included in the review involved students engaged in pair work or group work, such as peer mentoring [2] and peer instruction [3]. However, these studies did not focus on group work assessment for cybersecurity education.

Group work has been utilised in higher education for its well-known benefits to both instructors and students alike [4, 5, 6]. Working in groups facilitates discussion and the exchange of ideas among students during the learning process through which not only the understanding of subject contents are enhanced and innovative ideas refined, but also transferable skills such as oral communication, negotiation, cooperation, and teamwork, skills that are valued in industry, are promoted [7, 8]. Social interaction through group work has also helped to mitigate loneliness during pandemics, when learning and teaching activities were largely moved online [9], because authentic human interaction is a critical requirement both in the learning and teaching

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process and as a key to mitigate loneliness for online learners [10]. Pragmatically, group work assessment reduces the marking workload for the instructor, a challenge due to the increased class sizes in higher education in subjects such as computer science.

However, research has also reported that students can have a negative experience when participating in group work assessments [7], arising, for example, from cases in which cooperation does not exist within a group. Students may express their dissatisfaction regarding an uneven distribution in workload across a group or difficulties experienced in fitting into a group, not due to their academic ability but to social skills [11]. When such situations occur, students often have a poor learning experience and are unlikely to achieve the intended learning outcomes [12, 13, 14].

The above benefits of group work encouraged researchers to investigate the concept of designing an optimal group assignment for a specific study context [15]. Guidance on designing and assessing group work in higher education [16] includes the advantages and disadvantages of working in different group sizes compiled from the literature [17], however, to the best of our knowledge, no research has been carried out on student preference towards group work. Do students prefer to work in groups or to work individually if given the choice? For those who prefer to work in groups, is there a preference for the size of group? Such questions relating to preference, motivates a novel approach to designing a group work assessment in a network security module for final year undergraduate students.

In addition, this paper seeks to engage issues relating to EDI (Equity, Diversity and Inclusion), at the module level as part of the curriculum design [18, 19, 20], with the intention of embedding diversity and inclusion into the design of group work assessment. Diversity and inclusion have been advocated as a priority on the higher education agenda, as evidenced by university strategies and approaches towards EDI across the EU and the UK [21, 22, 23]. As stated by the UK Quality Code for Higher Education [24, 25] the means by which learning outcomes can be agreed, and achieved, need to be flexible to accommodate the diversity of students and inclusive to meet the student individual requirements. The driving force behind this is that demographically the university student body has become more and more diverse [26]. In response to this, some universities have set, at the strategic level, an EDI-oriented governance structure which may include initiatives such as widening participation; others have intrinsically created diversity and inclusion teams to support students; or set targets aimed at increasing the percentage of BAME (Black, Asian and Minority Ethnic) students achieving first- or upper second-class degrees [22].

Motivated by the above observations, the group work assessment for this study has been developed to explore the following research questions:

- **RQ1:** How do we design a group work assessment that includes practical tasks, that are diverse, inclusive and suitable, for large groups of students studying in cybersecurity?
- **RQ2:** What preference, if any, do students have between working individually and working in a group, given that the students are able to choose the size of the group?
- **RQ3:** Do student preferences have an impact on their results, and if so, what is the impact upon their results?
- **RQ4:** What are the rationale determining students' preference for different group sizes?

To answer the above research questions, two types of lab environment were carefully set up for the network security module and an assignment was designed aiming to be both diverse and inclusive [21, 22, 23]. The assignment tasks were then set in a way that enabled students to complete the tasks either individually or as members of a group using a virtual laboratory. During assessment design we took an inclusive approach by giving students a choice to select the group size and group members, or if they preferred, to work individually.

Such an approach does not force students to join a group, but allows students to choose their personal preference, in terms of group size and submission format. This approach provides students who may be shy to talk to team members and hesitant to contribute in a verbal context allowing more flexibility to suit their personal needs. However, unlike a diversity and inclusion officer providing extra help to students, the group work assessment did not label it as diverse and inclusive to students, but integrated the idea of diversity and inclusion in the design of the assessment itself.

The research methodology for this study included the following stages:

1. Design: At the coursework design stage the variant of assessments were developed to include diversity and inclusivity.
2. Data collection: During the three academic years, student preference and performance metrics were collected with a view to exploring trends and possible relationships.
3. Analysis: A statistical analysis for correlation between performance and student preferences were carried out.
4. Evaluation: At the evaluation stage questionnaires were used to explore the student rationale for their grouping preferences.

The rest of the paper is organised as follows. Section II introduces the design of the group work assignment and the network security laboratory environment. Section III presents the analysis of student preference to group sizes and submission formats in the three academic years 2020-21, 2021-22 and 2022-23 whilst section IV analyses the distribution of coursework marks and possible correlations between group marks and group size. Section V presents the results from a post-submission questionnaire on student rationale for grouping preference and student experience. Section VI discusses the impact of Covid on student choices, privacy issues and disputes relating to the allocations of marks. Section VII concludes the paper.

2. Design of the Assignment

The goal of this assignment was for students to apply the knowledge and understanding that they had obtained from the classroom to a laboratory based network scenario. The overall task was to create a network, run and observe normal traffic, launch network attacks, observe the impact on network performance, and finally use network defence mechanisms to protect the network and evaluate their effectiveness. From the student's perspective the assignment contains several levels of tasks based on network design and configuration, network attacks, network defence, and performance analysis.

2.1. Virtual Labs

Two lab environment were designed, the first for students working in groups of size one (individually), and the second for groups of size greater than one. The decision to introduce the group work was initiated by the Covid-19 pandemic in 2020 that forced educational processes to move online. Working in groups helped to mitigate learner loneliness and although the course itself did not have a learning outcome of cooperative learning, this was seen to be a beneficial outcome in challenging times.

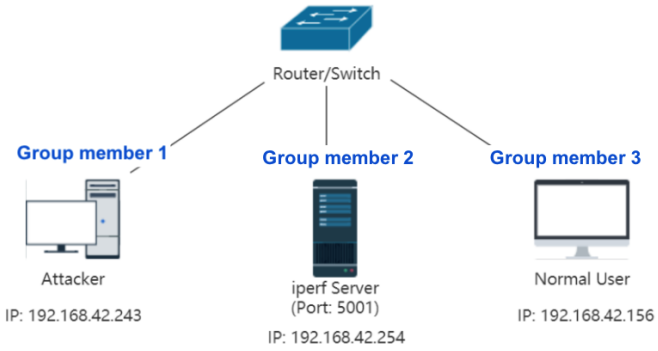


Figure 1: Group work environment: virtual laboratory. A typical network topology for a group of three members.

For groups of size greater than one, a virtual lab was set up in the cloud with virtual machines (VMs) that could be accessed by students remotely through a web-based terminal All student VMs for the module were Internet nodes on the same subnet. The assignment could be completed collaboratively by each group member working on their VM, playing a role, or multiple roles: attacker(s), victim(s) and defender(s) for the experiments. A typical network topology for a group of three members is shown in Fig. 1 where different group members act different roles (attacker, victim, defender) on the subnet. The group members themselves could be anywhere at separate locations; as long as they could connect to the Internet and launch their VMs, the VMs would form a virtual subnet in the cloud.

For those working in a group of size one (individually), an alternative lab environment was developed using [27], an open-source network emulator that students could download and install on their VMs or PCs. Subsequently they were able to build an emulated network composed of multiple Internet nodes on mininet to complete the assignment individually. The student had full control of all hosts on the emulated network which could each simulate the role of attacker(s), victim(s) or defender(s), therefore although working individually, the student could fully complete the set coursework.

2.2. Group Formation, Group Submission and Mark Distribution

Students were encouraged to form a group to complete an assignment. The module lead decided to allow groups of up to a maximum of four members, after considering the workload involved for the assignment, the role play involved for attackers, victims and observers, and being fair

to those students that chose to work alone. Students were given the choice to either work individually on the assignment or to form a group of any size within the allowed maximum. The steps used to establish groups were as follows:

1. Students formed and agreed a group offline by themselves. The module lead was not involved in this process.
2. When a student was willing to join but could not find a group the module lead introduced them to other students to see if they would like to form a group.
3. Students registered their group choices on the University Learning Management System (LMS) prior to a given deadline. Group memberships were made anonymous at students request. Students choosing to work individually must also register as a group (of size 1).
4. The module lead managed the groups when necessary for example deselecting students from a group if requested to do so or opening group registration for students who missed the set registration deadline.

Two submission formats were permitted: a report of up to 1500 words or a video of up to 20 minutes. In either format, the students were to clearly demonstrate how they completed the tasks set in the assignment. Each group should make just one submission to represent the group's work. It was made clear from the beginning that within a group, all group members would get the same mark as that awarded to the group submission so as to avoid any disputes that might arise after the assignment had been submitted.

3. Analysis of Student Preference

3.1. Preference to Group Sizes

Table 1 present the number of groups of size 1, 2, 3 and 4, the corresponding number of students choosing each groups size and their percentage of the total student number, for the 2020-21, 2021-22 and 2022-23 academic years, respectively.

In comparing the three years data on group size, we observe that the number of students working individually decreased during the period 2020-2023, from 26% in 2020-21, to 18% in 2021-22 and 17% in 2022-23. The group size 4 was the most popular for each of the three years and the number of students working in groups of size 4 in 2022-23 had a significant increase to almost half (49%) of the cohort choosing this option. This we feel can be explained by the changes in different teaching structures employed during the three academic years.

In 2020-21, due to the Covid pandemics restriction, all teaching was delivered completely online. This included asynchronous pre-recorded high-quality video lectures with transcripts, synchronous sessions for the whole cohort (206 students) on MS Teams led by the module lead, and synchronous sessions for small groups of 30 students on MS Teams led by teaching assistants. In 2021-22, the country was emerging from the pandemics, thus the module used a hybrid teaching approach. The students had access to the pre-recorded high-quality video lectures, however, synchronous sessions were delivered by the module lead twice, once in-person and once online. Synchronous sessions for small groups were carried out in computer labs in-person. In 2022-23, the students still had access to the pre-recorded high-quality video lectures, and all teaching returned to 100% in-person on campus. The in-person teaching gave students the

Table 1
Student Group Preference

Academic year	Group size	# of groups	# of students	% of students
2020-21 (N=206)	1	53	53	26%
	2	19	38	18%
	3	13	39	19%
	4	19	76	37%
	Total	104	206	100%
2021-22 (N=182)	1	32	32	18%
	2	22	44	24%
	3	14	42	23%
	4	16	64	35%
	Total	84	182	100%
2022-23 (N=237)	1	39	39	17%
	2	17	34	14%
	3	16	48	20%
	4	29	116	49%
	Total	101	237	100%

opportunity to meet their peers and to form groups, effectively reducing the percentage of students working alone on the assignment and increasing the percentage of groups with the largest size (4).

3.2. Preference to Submission Format

In all three years, only a small fraction of students chose to submit video rather than a written report (3 out of 104 groups (2.9%) in 2020-21, 4 out of 84 groups (4.8%) in 2021-22, and 3 out of 101 groups (3.0%) in 2022-23). These groups had sizes of 1, 3, and 4 respectively. This shows that the vast majority of students still preferred to submit a traditional written report in preference to a recorded video for their submission format.

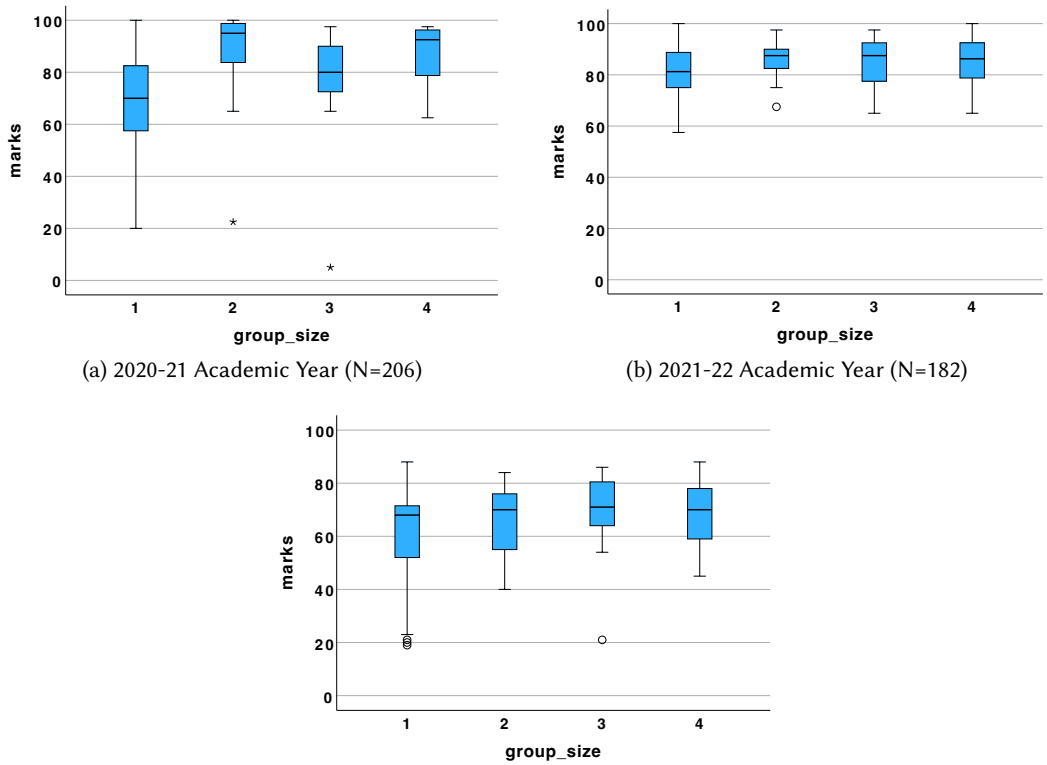
4. Analysis of Student Performance

4.1. Distribution of Marks

To perform the statistical analysis of student preference and its impact on their assignment score we used the SPSS (Statistical Package for the Social Sciences) tool [28]. Figure 2 illustrates the distribution of marks for the assignments for each academic year with respect to different group sizes using box and whisker plots. For all three years, it is notable that the range of marks for groups of size 1 was the largest, as can be seen from the whiskers of the plot in comparison to groups of other sizes. The plots clearly show that some students working individually achieved the highest marks (100% in 2020-21 and 2021-22, and 90% in 2022-23) similar to other groups working in sizes of 2, 3 or 4. However, some students working alone achieved the lowest marks among the cohort for each year. It was noted that some students had missed the deadline for group registration that left them with the option to perform the assignment individually.

They appeared to start the lab late, which could explain the low marks for the cohort working individually in all three years. In 2020-21 and 2021-22, the median marks for groups of size 1 were much lower than that for groups of other sizes, while in 2022-23, the differences were not so obvious.

In 2020-21, the box and whisker plots identified two 'extreme outliers' indicated by stars (*) (23 for groups of size 2, and 5 for the groups of size 3). The box and whisker plots also identified 'mild outliers', marked by a small circle. There was one mild outlier in 2021-22 for groups of size 2, which was the minimum score (68) for that group size. In 2022-23, several mild outliers were also identified for groups of size 1 with a cluster of low marks (19, 20, 21), and for groups of size 3 with the minimum score (21).



(a) 2020-21 Academic Year (N=206)

(b) 2021-22 Academic Year (N=182)

(c) 2022-2023 Academic Year (N=237)

Figure 2: Assignment results for three academic years

4.2. Correlation Analysis

4.2.1. Correlation between Group Size and Group Mark

To measure the relationship between the way in which the students preferred to do an assignment and their performance, first, Pearson's linear correlation coefficient [29] was employed to examine the correlation between group size and group mark. The correlation coefficient (r-

value) lies between -1 (strong negative correlation) and +1 (strong positive correlation). The typical threshold for the p-value (significance) is 0.05.

Table 2 shows that in 2020-21, there was a statistically significant result between group size and group mark, with a correlation coefficient of 0.310 (r-value), and p-value of 0.001 < 0.05, and confidence interval of 0.125 to 0.474. There was, however, no statistically significant result found for group size and group mark for 2021-22 and 2022-23 (p-value >0.05). The negative lower confidence interval means that group marks did not always increase with group size. The overall results suggest that group size does not have strong correlation with group mark for two of the three academic years.

Table 2
Correlations between group size and group mark using Pearson correlation

Academic year	Sample size	Correlation	p-value	Confidence interval
2020-21	104	0.310	0.001	[0.125; 0.474]
2021-22	84	0.125	0.256	[-0.91; 0.331]
2022-23	101	0.195	0.051	[-0.001; 0.376]

4.2.2. Correlation between Group Size and Group Mean Performance

To further explore if there are performance differences between groups, we used the F value calculated by the analysis of variance (ANOVA) tool. ANOVA is a popular tool used for looking at the different types of correlation in academic performance that tests equality among several means by comparing variation among groups (due to treatment) relative to variation within groups (random error) [30, 31, 32]. The F value calculation determines the ratio of explained variance to unexplained variance. If no real difference exists between the tested groups, which is called the null hypothesis, the F value will be close to 1.

We carried out a significance test for the outliers (see Fig. 2) and found that the outliers did not have a significant effect for ANOVA for each of the three years. We therefore proceeded with ANOVA using the complete set of the data collected for each year in turn.

Table 3
Results of correlations between group size and the mean mark of group using one-way ANOVA

Academic year	Sample size	F value	p-value
2020-21	104	6.089	<0.001
2021-22	84	0.954	0.419
2022-23	101	1.567	0.202

Table 3 shows that for 2020-21, the calculations by one-way ANOVA revealed that there is statistically, a highly significant difference between the mean marks obtained by groups of different size ($(F(3, 100) = 6.089,\ p < 0.001)$). To further assess the significance of differences between pairs of group means, the Tukey's Honest Significant Difference (HSD) test was performed, as a usual follow up test to one-way ANOVA, when the F-test has revealed the existence of a significant difference between some of the tested groups. Tukey HSD analysis resulted in two homogeneous subsets: subset 1 was composed of groups of size 1 and size 3

whist subset 2 consisted of groups of size 2, 3, and 4. Within a subset there was no significant difference whilst between subsets there was a significant difference regarding student academic performance (the assignment marks).

For 2021-22 and 2022-23, as shown in Table 3 it was found that there was no statistically significant difference between the mean marks of groups of different sizes by one-way ANOVA: $F(3, 80) = 0.954$, $p = 0.419$ for 2021-22, and $F(3, 97) = 1.567$, $p = 0.202$ for 2022-23.

5. Rationale for Grouping Preference

To understand the rationale behind students' grouping preference and their opinions towards the design of the assignment, a questionnaire was set up in MS Forms for the academic year 2022-23. During the week following the coursework submission deadline, all students (237) were invited to participate in the questionnaire on a voluntary basis. Seventy (70) students responded by completing the questionnaire. Among them, 10 participants completed the assignment as a group of size 1 (individually), 9 worked in pairs, 13 in groups of size 3 and 38 in groups of size 4.

Table 4
Responses to Question: What were your reasons for choosing to working individually? (N=10)

Option #	Option	# of responses	% of responses
I1	I preferred to work alone	6	60%
I2	I was confident that I could complete the coursework on time by myself	6	60%
I3	I thought that working individually would give me greater flexibility	6	60%
I4	I thought that working individually would give me more control	5	50%
I5	I thought that other students could slow me down if I worked in a group	2	20%
I6	I was unable to find other students to form a group	1	10%
I7	I thought that I might not be able to get along with others in a group	0	0
I8	I ran out of time to form a group	0	0
I9	Other	2	20%

The 10 participants completing their assignments alone represented 26% of all students working in groups of size 1 (individually) on their assignment (10/39). When asked the question: What were your reasons for choosing to work individually, as shown in Table 4, personal preference (I1), academic confidence (I2), flexibility (I3), and control (I4) were popular reasons for students preferring to work individually on the assignment. These responses were selected by half or more than half of the participants (5 or 6 out of 10 participants). Two students were concerned that other students could slow them down (I5) if they worked in a group. Unfortunately 1 student was unable to find other students to form a group (I6). Two students selected "Other" but did not provide further information.

The remaining 60 respondents represent 30% of all students that completed their assignments

Table 5
Responses to Question: What were your reasons for choosing to work in a group? (N=60)

Option #	Option	# of responses	% of responses
G1	I could benefit from discussions and we could learn from each other	41	68%
G2	I preferred teamwork	30	50%
G3	I knew the other group members well before the coursework	30	50%
G4	I thought working in a group of 2/3/4 would be the most efficient	29	48%
G5	I could share the workload	27	45%
G6	I thought teamwork would lead to a better coursework mark	21	35%
G7	I happened to find 1/2/3 other students to work with	11	18%
G8	I thought I could practise my social skills	10	17%
G9	I thought I would get along with the other members of the group	9	15%
G10	Other	6	10%

as members of a group of size 2, 3 or 4 (60/(34+48+116)). Table 5 presents their responses to the question: What were your reasons for choosing to work in a group? Approximately two third of the participants believed that they could benefit from group discussion and peer learning (G1). Approximately half of the participants chose group work due to their preference for teamwork (G2), existing friendship (G3), work efficiency (G4), and workload sharing (G5). Getting a higher mark was the next most popular response chosen by approximately one third of the participants (G6). Eleven students happened to find other students to form a group. Social aspects of group work were also shown to be an incentive for students to choose working in a group (G7, G8, G9). Six students chose ”Other” but no further information was provided.

6. Conclusion

The three-year study demonstrates that careful design and technical support in laboratory environments can produce a group work assignment that puts the students at the centre of the design, giving them a meaningful and personalised choice that matches their learning needs and preferences, preserving diversity and inclusivity. The analysis showed that the variations in teaching structures in relation to the Covid pandemic has had an impact upon students' grouping preference. Students also revealed that personal preference, academic confidence, peer learning, workload sharing, flexibility and efficiency are popular rationale for their grouping preferences, establishing their personalised learning style. The correlation analysis of the three-year data indicated that there is no strong correlation between grouping preference and their academic performance. These results and analysis suggest that a diverse and inclusive group work assessment with personalised choice can be used with large groups of students without introducing bias into student performance.

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