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Examining the role of group work as an effective instructional strategy when teaching problem solving

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This paper reports on a post-primary classroom intervention conducted to investigate the effect that carrying out problem solving in small groups as an instructional strategy has on the problem-solving performance of individual students. Over the course of the 6-week intervention students were introduced to an explicit problem-solving framework and challenged to solve weekly problems both in small mixed-ability groups and also individually during their traditional mathematics classes. It was found that there was a strong correlation between the problem-solving performance of the small groups and that of the individual students which suggests that group work could be utilised as an effective instructional strategy when teaching problem solving.

Keywords: Group activities, problem solving, secondary school students, secondary school mathematics.

Introduction

In 2008 in Ireland there was a change in the mathematics syllabus in secondary education in response to a number of studies and publications (e.g. Conway & Sloane, 2005). All of these studies identified that there were major deficiencies in the mathematical competency of students in secondary education and those commencing third level education. These concerns, along with others, fuelled the introduction of a new secondary mathematics syllabus in Ireland in 2008 named *Project Maths*. Project Maths identified five key skills that they saw as being central to effective teaching and learning across the new curriculum - *information processing, being personally effective, communicating, critical and creative thinking and working with others* (DES, 2015).

This new secondary mathematics curriculum also places an increased emphasis on group work and the development of problem solving skills within the classroom. This syllabus change should lead to an increase in the amount of group work occurring within Irish classrooms, but this begs the question as to how effective group work actually is? Can we measure what effect group work will have on the individual student, particularly when dealing with activities such as problem solving?

In terms of problem solving it has long been accepted that increasing the problem solving skill set of students is one of the primary goals of mathematical instruction (Travers, 1977). In the early nineties in America, the National Council of Teachers of Mathematics (NCTM) set out the goals for promoting problem solving as a curricular focus by declaring it as one of the three main goals of mathematical instruction in a second level school (Szetela & Nicol, 1992). In Ireland this focus on problem solving has only taken place in recent years due to the change in the syllabus brought about by the new Project Maths course. Many research papers focus on the individual problem solver but others have focused on the idea of problem solving in small groups (Artzt & Armour-Thomas, 1992). In addition to the obvious benefits of improving the problem solving skills of the students research highlights the additional benefits that working in small groups yields e.g. developing personal and social skills (McGlenn, 1991), enhancing self-esteem (Slavin, 1991) and reducing the dependency of

the students on the teacher (Sandberg, 1990). In light of these benefits and the emphasis that the new syllabus places on working with others and problem solving, this current research project decided to examine whether working in small groups to complete mathematics problems would improve the general problem solving ability, and overall mathematical ability, of individual students. This research aimed to address this hypothesis by answering the following questions:

1. Is there a relationship between an individual student's problem solving achievement scores and their achievement scores when solving problems as part of a group?
2. Do students believe that working in small groups to solve problems is beneficial in the development of their individual problem solving ability or overall mathematical ability?

Framework for problem solving

With the increased emphasis placed on problem solving in the new syllabus, and the relative newness and unfamiliarity of both teachers and students with problem solving, it was deemed necessary to provide students with guidelines to assist them during their initial problem solving exploits. The instructional framework selected by the authors to assist in the problem solving activities in the classroom was developed by Artzt & Armour-Thomas (1992) and was specifically tailored for problem solving in small groups. This framework was based on an earlier framework developed by Schoenfeld in 1985 but expanded and added additional episodes. Schoenfeld (1985, p. 292) defined an episode as “a period of time during which an individual or a problem-solving group is engaged in one large task”. Artzt & Armour-Thomas (1992) finally settled on eight episodes when looking at problem solving in small groups – *read, understand, analyse, plan, explore, implement, verify, and watch and listen*.

Methodology

Participants

34 students from a medium sized rural secondary school in the west of Ireland participated in the research project. 22 of the students (12 male and 10 female) were from a mixed ability first year class (average age 13 years) whereas the remaining 12 students (7 males and 5 females) were from an ordinary level¹ third year class (average age 15 years). The first year cohort only had two classes per week with their teacher as part of this intervention whereas the third year group had four classes per week with their teacher over the course of the six week intervention. A typical mathematics class lasts for 40 minutes.

Selection of content and questions

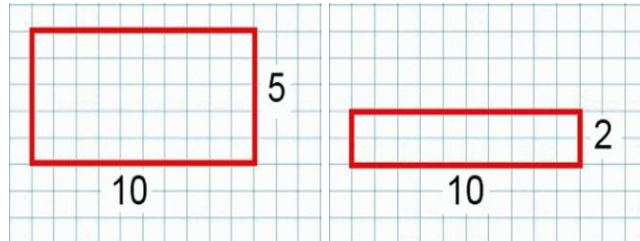
The selection of content for this study was primarily based on the Project Maths Junior Cycle² syllabus. The topic covered by the first year students during the six week intervention was ‘area and perimeter’, whereas the third year students covered the topics of ‘circles and cylinders’ and ‘area, perimeter, and volume’. Note that the third year cohort covered more material due to the extra contact

¹ After first year all classes in Irish secondary schools are streamed into two groups, Ordinary and Higher, with higher being the more challenging stream.

² The Junior Cycle caters for students aged from 12 to 15 years and covers the first 3 years of post-primary education.

time with their teacher during the intervention. An example of a question given to the first year students whilst working in groups is provided here:

The first rectangle has a perimeter of 30 units and an area of 50 square units. The second rectangle has a perimeter of 24 units and an area of 20 square units. Charlie wondered if he could find a rectangle, with a side of length 10 units, whose perimeter and area have the same numerical value.



Each week during the intervention the students were challenged to solve some combination of either purely mathematical or worded problems based on the previous week's mathematical content. Verschaffel, Greer, and De Corte (2000) use the term 'word problem' to refer to any mathematical task where significant background information on the problem is presented as text rather than in mathematical notation and this is also the meaning that the authors have adopted as part of this study. Problems were selected from past examination papers, books and online websites and were deemed appropriate for the age and ability levels of the students.

Intervention and assessment

The intervention took place in the students' traditional 40 minute classes over a period of six weeks. Normal teaching operations took place during the intervention with approximately 10 minutes of certain classes being assigned to the testing of the students' problem solving abilities. In the first week of the intervention the students were given an individual assessment to gauge their initial problem solving skills prior to working in groups to solve problems. During the following five weeks students were regularly placed in small mixed ability groups of 3 or 4 and asked to solve 4 problems together during that week. At the end of each week students were asked to individually solve 2 problems so that their individual progress could be monitored. Individual students and all the members of a group were awarded a single correct mark if the problem was answered correctly and awarded no mark if they failed to correctly solve the problem. A focus group with 6 students randomly selected from both the first and third year groups was conducted following the intervention.

The role of the teacher during the intervention

Throughout the intervention the primary role of the teacher was that of a facilitator or a time-keeper. The teacher answered any questions that the students had with regards to the use of the problem solving framework or specific questions such as issues regarding units of measurements (i.e. is cm^3 associated with volume). When asked a question related to the solving of the problem the teacher declined to answer directly and instead used probing questions to try and guide the students towards a solution. The frequency of questions directed at the teacher lessened after the initial weeks of the study as students began to rely on the other members of their group for assessing their ideas and potential solution strategies and not the teacher. Fewer questions were directed at the teacher during

the individual problem solving sessions as the students viewed these more as ‘tests’ and therefore assumed that they were not supposed to ask questions of the teacher.

Findings

First-year students

Looking at the assessment trend among the individual students it can be seen from Figure 1 that over the course of the intervention there was an upward trend in the number of questions answered correctly. The pre-test resulted in only 5 correct answers (11.36%) out of the possible 44 (22 students times 2 problems). This number of correct answers increased to 16 (36.36%) in week 1, 28 (63.63%) in week 2, 30 (68.18%) in week 3, 31 (70.45%) in week 4, and finally 38 (86.38%) in week 5. From Figure 1 it is clear that there is an almost linear increase in the number of correct responses between the pre-test and the week 2 assessment but this increase is then followed by 2 weeks of a much slower advancement by the students before increasing more significantly in the final week.

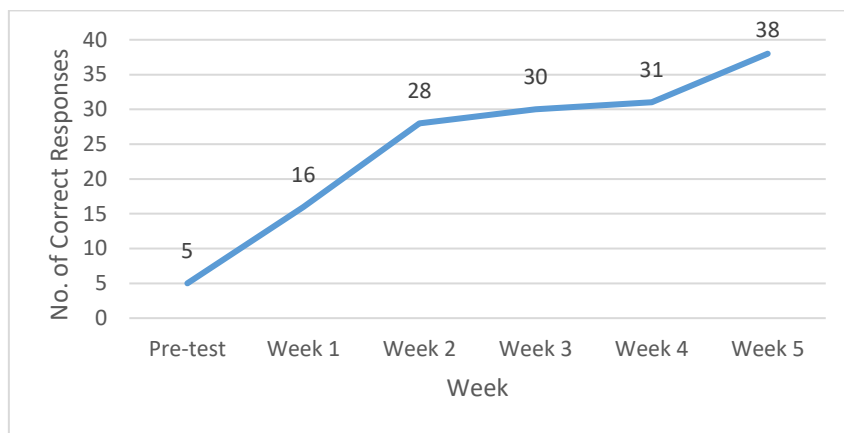


Figure 1: Individual assessment scores for first year students

In terms of the group assessment, Figure 2, there was evidence of a positive increase in the number of correct group responses as the weeks progressed. Out of a total score of 24 (6 groups times 4 problems) possible correct responses each week 8 groups (33.33%) answered the problems correctly in the first week. This increased to 17 (70.83%) in week 2, remained at 17 for week 3, increased marginally to 18 (75%) in week 4 and increased again to 19 (79.16%) in week 5.

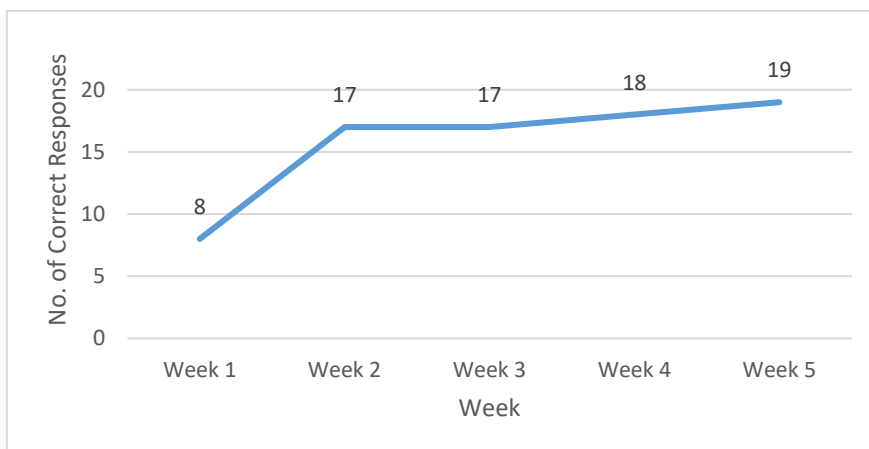


Figure 2: Group assessment scores for first year students

Comparing the number of correct individual solutions against the number of correct group solutions each week it was found that there was a strong correlation between the number of correct answers among individual students and among the groups ($r = 0.95$). This suggests that as the first year students became more efficient at solving problems within groups so too did they become more efficient at solving problems individually.

Third-year students

Similar trends are noticeable among the third year group in both the individual and group problem solving assessments, although the scale of the improvement is not as significant as with the first year students. The pre-test of the individual students problem solving ability resulted in 2 (8.33%) correct responses out of a possible 24 (12 students times 2 problems). At the end of week 1 the number of correct responses had decreased to 1 (4.16%) before increasing to 14 (58.33%) at the end of week 2, 15 (62.5%) at the end of week 3, 22 (91.66%) in week 4 and then dropping slightly again to 19 (79.16%) in week 5 as seen in Figure 3.

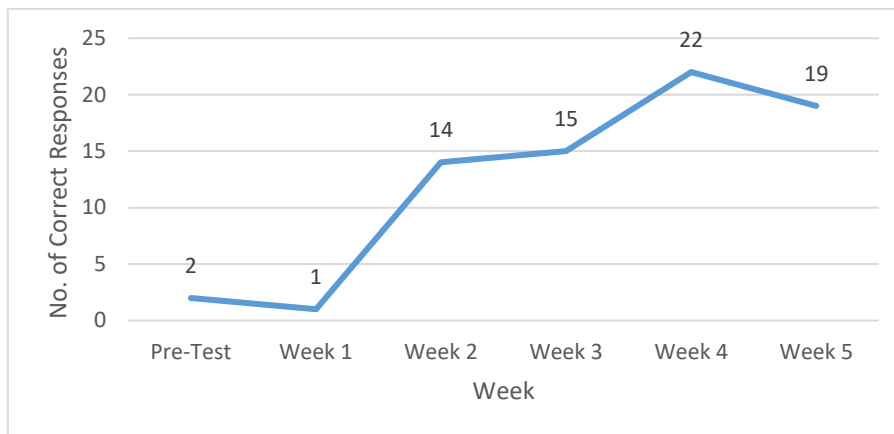


Figure 3: Individual assessment scores for third year students

In terms of the number of correct responses from the groups of third year students there appears to be less fluctuation in the results. Out of a total score of 12 (3 groups times 4 problems) 4 groups (33.33%) answered the problems correctly in the first week. This increased to 6 (50%) in week 2, 7 (58.33%) in week 3, 10 (83.33%) in week 4 and 11 (91.66%) in week 5 as seen in Figure 4.

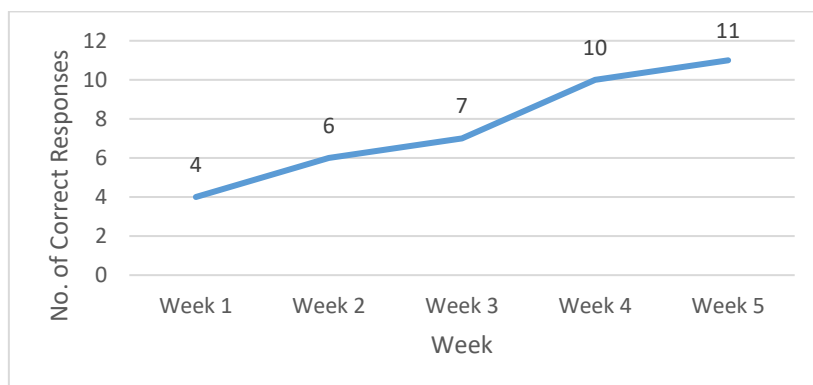


Figure 4: Group assessment scores for third year students

Comparing the number of correct individual solutions against the number of correct group solutions each week for the third year class again found that there was a strong correlation between the number of correct answers by individuals and among the groups ($r = 0.889$).

The second research questions focused on whether the students felt that working in small groups to solve problems had been beneficial in enhancing their individual problem solving skills or their overall mathematical skills. Overall the students were positive in their responses to the focus group question relating to whether they felt that their individual problem solving abilities had improved as a consequence of the intervention.

Interviewer: Do you feel that your problem solving ability has improved? Why do you think this?

Student4: I think it has because I have been finding it easier to figure out my homework, so I think it has.

Most students responded in a similar manner although two of the group did confuse the question slightly and make reference to working in groups.

Student2: Ah, yes because I now know that I can ask others for help and use their opinions to build on to get my answer.

As already alluded to by some of the students in the previous question, all of the students responded that they found working in small groups enjoyable and some even stated that it increased their confidence in the mathematics classroom. Worryingly some of the students appeared to suggest that this type of active is not common place in their traditional classroom which is in opposition to the overall aims of the new syllabus.

Interviewer: How did you find working in groups as part of your mathematics class?

Student1: I enjoyed doing maths more because I got a fair share of trying to work it out and it wasn't as boring as a normal maths class. I felt like my opinion mattered which is different to other classes. I found it weird that the teacher encouraged us to talk while in class, usually they are trying to keep us quiet.

Student5: I feel more confident because maths seems a bit more fun when you can talk to your friends. Also it improved my ability to say I could do things when I thought I couldn't. I now try a different way of answering the question if I get stuck when I try it the first time around.

When asked about whether working in groups was beneficial in helping them solve the problems all the students agreed.

Student5: Am, yes because it helps it go faster and if you're stuck you'd have another person's opinion to help work it out. It was really fun working with your friends in class like that.

The final question focused on whether or not the students felt that, as a result of their participation in the intervention, their overall mathematical knowledge had improved. The responses to this question were positive, but varied. Some students focused on the idea of being able to approach questions differently now because they were able to ask other students their opinions and then solve the problem

themselves, based on the insight from the other student. Another student spoke about being able to analyse the ideas of the other members of their group and how it forced them to look at the problems from different perspectives.

Interviewer: Have the classes improved your overall mathematical knowledge? In what ways?

Student2: I think that I have new ways of solving problems. Before the group work, I used to look at the question and if I couldn't understand I used to leave it because I didn't know what to do. Now I would ask someone else if they could do it and see if I could use their idea to answer it.

Student3: I found it improved my knowledge because I think I had to think more about the question.

Interviewer: What do you mean by 'think more'?

Student3: Am, well because if someone in the group had a different opinion, I would try to see where they got that idea from and try and see if that would work. I also tried to see if it was the same as my idea but said in a different way.

Conclusion and discussion

The primary aim of this study was to investigate whether problem solving in small groups had any effect on a student's problem solving achievement when working on their own. Solving problems in small groups affords students the opportunities to ask questions, challenge assumptions, discuss opinions and share work among colleagues. The results of this study found that there was a strong positive correlation between the weekly number of correct responses to the problems solving tasks in small groups and the problems solved by individual students in both of the student groups. This would suggest that working in small groups to solve problems has had a positive impact on the individual problem solving skills of the students. Reading too much into this results could be misleading though as the unfamiliarity of the students with problem solving, or problem solving approaches, meant that the improvement in overall problem solving skills shown by the students could be a consequence of being introduced to a problem solving framework rather than from working in small groups, or some combination of both.

This been said, all of the students commented positively when asked about whether they felt that working in small groups had been beneficial to them. The students highlighted how they liked the ability to talk to this classmates and discuss the problem which was not something that was common in their previous mathematics classes. This seems to contradict the aims of Project Maths which stresses the importance of developing the key skills of *communicating* and *working with others* (DES, 2015). In line with the finding of Slavin (1991) students commented positively about several qualities which they felt that working in groups had helped to develop, such as feeling like this opinions mattered and feeling more confident towards mathematics. Additionally Sandberg (1990) found results that coincide with the findings of this study in that students are willing to persevere when faced with a problem that they cannot solve straight away and overall become less dependent on the teacher. These are all key skills that need to be developed in students and this would suggest that the teaching of a problem solving framework in conjunction with working in small groups to solve problems appears to be an effective instructional strategy.

Finally it is worth noting that the students did highlight some issues with the intervention in its current form. Two students commented that they felt that there wasn't enough time allocated to the group work activities at the end of the classes and that they always felt rushed. Another two students commented that in one instance one student in their group had taken over the activity and proceeded to solve the problem by themselves without consulting or involving the other members of the group. Obviously there are limitations to every study but going forward it is important that more focus be placed on the roles and monitoring of individual students within the groups.

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