Visibly Random Grouping Applied to First-Semester Engineering

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Introduction

This complete evidence-based practice paper is based on visibly random grouping (VRG). This technique, introduced in the mathematics education literature in 2014, has been shown to have a variety of benefits [1] [2]. While there may not have been sufficient time for this technique to be a key component of additional research studies, the approach is frequently credited, particularly on the web sites of K-12 mathematics instructors, as having a profound positive effect on classrooms and students [3] [4] [5]. There is strong agreement between the research findings and the first-hand accounts of the teachers, as described below. In the VRG model, student groups are formed truly randomly, and the students can see that it is random. In other words, it is obvious that neither the teacher nor the students are choosing the groups. One common method is by having students draw a card indicating a particular seating location when they enter the classroom. Liljedahl found that having the students do so on a daily basis worked well for the mathematics course he studied [1].

One benefit of this approach is that students develop better teamwork skills, helping create an environment where students share and collaborate with each other [6] [7] [8]. Over time, students reach the point where they work together "quickly and freely" in a new group [9], no matter who else is in the group with them [8]. One teacher reports that her students listen more attentively to each other than they did before [10] and exhibit fewer unproductive behaviors [11]. The approach also results in elevated engagement and enthusiasm [1] [2] [7], which one source describes as a "greater willingness to take risks and engage with challenging tasks" [9].

Perhaps as a result of improved teamwork skills combined with frequent switching of groups, Liljedahl reports that VRG leads to sharing of knowledge between students on a larger - sometimes classwide - scale, an increase in students co-constructing understanding, and a decrease in reliance on teacher validation [1] [2]. Sometimes this can be seen as richer conversations about problems [6], engaging students from other tables in class discussions, or directing less comments and questions to the teacher [10]. As one teacher describes, "I had never even thought about mobility of knowledge between students as a variable I could influence in my classroom. But over time, I saw much of what Liljedahl described happening." [9]

A final benefit that is seen in both Liljedahl's papers and the accounts provided by teachers is the breaking down of social and other barriers. When teachers choose the groups, there is usually a reason for putting particular students together (or keeping some students apart). Students know this, and therefore try to determine the roles the teacher intended for them in whatever groups the teacher assigns [12]. Students can easily feel that they are supposed to be the "smart one," "dumb one," or "in the group of troublemakers" and then may act accordingly [9] [13]. They might also read unintended teacher motives in the demographic composition of a group [13]. When the students know the groups are random, they know there are no ulterior motives related to academic ability or demographics behind the composition of a particular group [9].

The benefits described above are attributed to two important elements of the approach: the short-term nature of the groups and the students seeing that the groupings are generated randomly [8]. As stated previously, Liljedahl found that changing the groups daily was effective, and most who report adopting the practice also use that frequency of switching. There have been some variations. One teacher who has 90-minute periods sometimes switches twice in a class [7]; some high school science teachers found that changing seats once a week worked well with less logistical overhead [14]. The important part is that the students believe the groups are of short enough duration that they can endure working with even their least ideal teammates [1] [8] [14]. Making the random nature of the grouping visible to the students eliminates the second-guessing of potential teacher motivations for groupings, sends the message that all students can contribute to their classmates' learning, and generates student buy-in and participation [1] [7] [10] [12] [13]. Instructors must show a commitment to honor the random results, even if they sometimes put students together that they would normally not want to work together or result in some students working together more frequently than others [1] [12].

Although the bulk of the application of VRG has been in K-12 mathematics, there is reason to think the approach could be effective with first-year college engineering students. The claimed benefits of VRG - improved teamwork skills, co-construction of knowledge, and the breaking down of social barriers - are among the non-content goals that many first-year engineering instructors may have for their courses. While students are transitioning to college and learning the engineering culture, it is vitally important for them to learn to work effectively with teams of diverse people and find community [15] [16]. Further, what instructor would not want to see increased student engagement and enthusiasm?

Some first-year engineering instructors at The Ohio State University discussed the potential implementation of VRG in their first-semester courses and then used some aspects of this approach. This work describes the variations that were implemented by three different instructors, along with the rationale for each form. At the end of the semester, students were asked to reflect on the strengths and weaknesses of whatever grouping technique was used in their section. A qualitative analysis of all of these data has led to a description of the experience from the perspective of the students. Further, the trends that emerged from these engineering student descriptions were compared to and contrasted with the benefits described (largely by instructors) in implementations in mathematics courses elsewhere.

Course Background, Description, and Setting

The work described was situated in the first-year engineering honors program [17]. This program, which has enjoyed a rich history, typically serves between 350 and 450 students per academic year. Almost all of these students live on campus. All students take two semesters of engineering fundamentals, and also, depending upon their intended major and background, choose their math and science courses from two special honors physics courses, two honors chemistry courses, an engineering mechanics honors course, two accelerated calculus honors courses, and a special linear algebra course. The students are not arranged into specific cohorts that share the exact same schedule, but they do tend to see many familiar faces in each of their

courses. The visibly random grouping was conducted in some sections of the first-semester engineering honors course.

This course has two components: engineering fundamentals and hands-on laboratory exercises. In the engineering fundamentals portion of the class, which occurs threes time per week and is led by a faculty member, students are introduced to engineering problem solving; get exposed to engineering ethics; and learn how to use computer software for word processing, spreadsheets, and programming in C/C++ and MATLAB. In the laboratory portion of the class, which occurs once per week and is led by a graduate teaching associate (GTA), students conduct bench-top experiments to investigate fundamental engineering concepts, with a variety of experiences to introduce elements of each of the engineering disciplines in which a student could choose to major. Lab reports or lab memos are assigned most weeks to develop technical written communication skills. Several of the lab reports in the later portion of the semester are assigned as group reports.

The class is offered in multiple parallel sections that are physically capped at 36 students apiece. Students meet in the same room for all class sessions, including the lab. The classroom is configured to encourage active collaboration among the students and to promote a sense of community. Students sit at tables of four, facing each other, and each seat is equipped with a computer. Additionally, markers and a whiteboard of approximately 2 ft. by 2.3 ft. are placed on each table to further facilitate collaborative discussion. The tables are large enough to provide ample space for laboratory activities. This classroom arrangement was thought to provide an excellent environment in which to apply VRG.

Variations of Implementation (or not) of VRG

As stated earlier, there were variations in the ways instructors incorporated elements of VRG in their course sections. One of the instructors had heard about the technique and shared her ideas for implementing it with the rest of the group. Each instructor individually chose whether to implement VRG, try some variation of it, or not use it. The seating arrangements that resulted fell into three major categories. It was not the intent to set up a controlled experiment, but as it became clear that each variation had its own positive and negative aspects, information was gathered about each approach. This information is described in the following paragraphs and will also be summarized in Table 1 later in the paper.

Instructor A was relatively true to the model described in the literature, but opted to switch the groups once a week, rather than daily. When students arrived for the weekly lab session, they would pull random cards telling them at which table to sit. They would sit at the same table until the following lab. Choosing lab day as the day to switch seats was intentional, with the thought that this would facilitate the writing of group lab reports, when they were assigned. Instructor A taught two sections of the course.

Instructor B did not vary the students' seats, except for labs. In his two sections, students sat in the same assigned seat for every non-lab day for the entire term. On lab days, students were placed in pseudo-random groups just for the lab experience. The pseudo-random groups were determined by a seat-shuffling spreadsheet arranged such that in lab each week a student would

be working with three new students that they had not worked with before. The idea was that each student would work with almost every other student in the class over the course of the dozen lab days. The students returned to their originally assigned seats on the following class day.

Instructor C chose an approach that was essentially a hybrid of the two outlined above. Like Instructor A's class, the students received a new seat assignment each lab day and then stayed in that seat until the following lab. Like Instructor B's class, the new lab groups were not determined with VRG. Instead the groups were pseudo-random, determined by the same seat-shuffling spreadsheet process used by Instructor B. Students would consult a list of the new teams each week when they entered the classroom for lab to learn their new seat assignments. They would remain in that seat until the next lab day.

One thing to note about all of these approaches was that, with the seat switching occurring in the laboratory, the fidelity of each approach was somewhat dependent on the GTAs, since they were responsible for the laboratory sessions. For the most part, it appeared that the GTAs were on the same page as their supervising instructors. However, Instructor C found that the GTAs had somehow altered the spreadsheet, and so his students worked with some of the same people multiple times, rather than with the intended new table mates every week.

Assessment

To understand the student perceptions of each of these approaches, the following items were included on the end-of-course survey:

1) Which of the following options best describes how often you switched who you sat with on non-lab days? (Options were never, once or twice a semester, most weeks, about once a week)
2) Please briefly describe any benefits to this frequency of seat switching.
3) Please briefly describe any shortcomings to this frequency of seat switching.

The survey was administered electronically, and a small amount of course credit was awarded for its completion.

A content analysis was done by qualitatively coding the responses to the second and third questions; those codes were counted for frequency. The number of responses that could be coded for each of the questions is noted in Table 1. Responses are less than the number of students in the course sections, due to a combination of unsubmitted surveys, blank answers, and apparent misunderstandings of the questions.

Table 1. Analysis Groups

Instructor	Frequency of Switching	Visible or Not	Random or Pseudorandom	N benefits	N drawbacks	N possible
A	weekly	visible	random	60	58	66
B	never	not	N/A	48	55	70
C	weekly	not	pseudo	50	47	66

As might be expected, there were some distinct differences in the student feedback, depending on which grouping approach they had experienced.

No switching

Instructor B's classes, who had a different group for each lab, but otherwise remained in the same seats all semester, had a set of responses that, as might be expected, were quite different from the other sections. Over 70% of the respondents stated that the seating arrangement allowed for them to get to know those at their table well and to develop relationships. Nearly a quarter of them wrote about helping each other and having people they felt comfortable asking questions. One response summarizes this viewpoint nicely: "I thought that sitting with the same people everyday [*sic*] made it so that I truly formed a relationship and could ask for help from them both inside and outside of class. I would not have had it any other way." Some other perceived benefits that were mentioned by one or two students included developing a sense of team, allowing different people at the table to take turns leading conversations, learning the strengths and weaknesses of those they were working with, and not having to adapt to new people.

When asked about shortcomings of the approach, 55% of these students indicated that they would have liked to get to know more of the students in their section. As one student said, "…while I came to know the people I sat with really well, I didn't get to really know or meet people sitting at other tables and probably couldn't tell you most of their names much less knowing how to ask them for help [*sic*]." A couple of students wished they could have moved to different locations within the room more often, a few found it difficult to communicate with their lab groups, and a few didn't like their tablemates (or their tablemates' work habits.)

Random switching

Instructor A's students, who experienced authentic visibly random grouping, expressed a more varied set of benefits. Almost 70% of these students cited getting to meet their classmates. Almost a third of the students valued working with a variety of other students, pointing to differences in background, ability, and/or perspective as being helpful. One student articulated, "It let me meet a whole bunch of people and get new perspectives. I think new perspectives and new ways of thinking are extremely important to engineering and coming up with unique solutions to problems so this was very helpful." There were nearly two dozen other benefits described by at least one student, many of which could be related to developing good team work skills. Several students also said the experience made the course enjoyable.

As far as drawbacks were concerned, just over a third of the students completing the survey said that they did not get to know the other students in the class well. A little over 10% of the students wished that they had not experienced as many duplicate team mates as they did. The third most common response, by just under 10% of the respondents, was that there were no drawbacks. Some other aspects that students did not like about the experience included the lack of consistency, not always connecting with the group of the week, sometimes having a bad group, and not getting to choose where to sit in the room.

Pseudo-random switching

The benefits identified by the C group were very similar to those identified by those who had random grouping in group A. Seventy percent of this group cited meeting other people in the class as a benefit. Just over 30% said they liked working with people different from themselves. As one student said, "You got to meet nearly all of the people in the class and got to work with people of different abilities and strengths." Other benefits included learning to work with others, getting a change of pace, and not being stuck with a bad group for more than a week.

When asked about the shortcomings, the most common response from this group was that there were none; almost 20% said this. The shortcomings identified by this group were more varied than the benefits, with 15% saying they did not get to know their classmates well ("You never get to know a person that well or deeply unless you spend time with them outside of class."), almost 15% saying they worked with more duplicate teammates than they would have liked ("There were a lot of people I worked with more than once."), and just under 10% citing working with poor team mates ("Sometimes the group you get doesn't always match your work ethic.").

Discussion, Conclusions, and Future Plans

Generally speaking, the students in all three variations reported more benefits than they did shortcomings. It seemed that they were generally happy with whatever they had experienced. Some even stated as part of their response that they would not have wanted a different approach. However, there was stronger agreement in the classes that never switched in identifying the major benefit (relationship building) and most common drawback (not getting to know most of the class). The students who did switch, whether it was according to a truly visibly random scheme or a pseudo-random scheme, found it a benefit to meet and work with many of their classmates, but wished that they had the opportunity to form some deeper friendships through in-class work. The students from the visibly random grouping sections indicated that a more planned rotation that would result in less duplication of team mates would be beneficial. Since there were some discrepancies in how the GTAs for the pseudo-random grouping sections applied the spreadsheet, these students also suggested less duplication of teammates.

Several of the benefits identified by students in the groups that rotated weekly resonate with those previously reported, including valuing working with different kinds of people [1]. Liljedahl and others also reported students articulating that working with a bad group was more tolerable in a set-up where the groups change frequently, because it was known to be a short-term situation [1] [8] [14]. However, one major difference between earlier implementations and the data collected here is with respect to whether the new groupings were determined in a visibly random manner or not. Liljedahl found that some students only bought in to the approach once it was absolutely clear that the instructor was not manipulating the groups "behind the scenes," and this is consistent with the reports of several teachers [1] [8] [12]. In contrast, the feedback from these engineering students indicates that they would rather have the groups be pseudo-random so that they would work with a greater variety of people and experience less duplication of table mates.

A major difference between Liljedahl's approach and that used by Instructors A and C was the frequency of the switching. Liljedahl recommends switching daily, while in this course the switching happened weekly. It was the perspective of Instructors A and C that having the students sit with the people with whom they were writing group lab reports led to that work getting completed with greater ease and less drama than had been experienced in the past. This, in addition to reducing the logistical overhead, was a primary reason they opted for the weekly switching. While the effect on group report writing was not frequently cited by students as one of the benefits of the setup, they did not have the experience of doing it differently. Instructor A commented that the only group lab report communication difficulty she was aware of during the term was due to student absence, and that this was a welcome change from the low-level panic she recalled being a regular part of group lab report assignments in the past. Even when students were writing individual lab reports, it was easy for them to consult with others about procedures or data.

In general, Instructor C was surprised that the GTAs were not as comfortable using the group switching spreadsheet as he had seen in the past. In retrospect, most of the GTAs were working with two different instructors, and it is somewhat understandable that some mix-ups in approaches may have occurred. Still, this experience indicates that any instructor wishing to use this spreadsheet in the future should insure that the GTAs understand its intended use and follow it.

Given the feedback from the students in Instructor A's section that they would like to avoid duplicate table mates, she is planning to use the spreadsheet next year, as well. This means that both Instructors A and C, and probably several of the other course instructors, will be using an approach that could be called visibly pseudo-random grouping under the conditions that students switch groups on the day of their lab and then remain sitting with that group until the next lab. As a means of addressing any concerns that the pseudo-random spreadsheet seat assignment process is not "visible" or "random" enough, all instructors using it will present to their classes a description of the process and display images of several worksheet pages to reinforce the assertion that the instructor will not be manipulating the seat assignments. Students will thus realize that there are no ulterior motives related to academic ability or demographics behind the composition of a particular seating arrangement if the instructor can declare on the first day of class, "I don't even know you yet, but I know where you will sit each week of the term." Instructor B will use the visibly pseudo-random grouping in one of his two sections. His second section is the only section which has a mix of engineering students and business students with the desire that a balanced mix between engineering and business students at each table be maintained. The students next year will provide the feedback on whether the benefits of the pseudo-random approach outweigh the drawbacks.

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