The Connection Commonalities in the Mathematical Content of Lesson Sequences

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Abstract. This study examined whether there are any connections between the Year 8 mathematics content of the lessons of four competent mathematics teachers in two different school settings in Brunei Darussalam. A continuous series of lessons was video recorded, ranging between four to six consecutive lessons for each teacher participant. The qualitative approach analyses reported firstly, the connections in the mathematical content made between the teachers collectively, and secondly, the particular connections made by the individual teachers in each of their lesson sequences. The commonalities found among the teachers were on the topic of statistics and the close similarity between the combined lessons of the two teachers in the second school setting. Although two teachers made visible connections by making references to the content that was used in their previous lessons, only one of them consistently connected or made apparent references of real-life examples to several problem tasks among his lessons.

1. Introduction
Mathematics has been one of the most challenging subjects offered in schools throughout the world. There is usually a consistent abundance of students in each grade group who perform poorly in Mathematics, for both national and public examinations, due to a wide variety of factors that contributes to the productivity of the students and how well they perform [1-8]. Accordingly, the use of unsatisfactory and detrimental strategies intended by teachers is one of the many suspected reasons of low achievements in Mathematics[9-20]. There are several ways to connect the content taught across lessons. However, the extent to which a teacher value making the connections from one lesson to the next is seldom utilized. Sullivan [21] suggested that there are six key principles for effective teaching in Mathematics, and one of them includes establishing on what students know, creating and connecting students with anecdotes that both contextualize and establish a rationale for the learning. Making connections between lessons is highly efficacious in teaching Mathematics. Consequently, making connections between topics and lessons is vital in order for the students to understand and be proficient in mathematics.

There is a plethora of ways a teacher can exert connections in mathematics and apply between lessons, such as providing extensive opportunities to learn as offered by the syllabus through the teachings of concepts, which may help the students to generalize and apply their knowledge to practices throughout their academic years [22]. Furthermore, Eli and colleagues [23] conducted a study to assess the value of making mathematical connections and its relationship with mathematical
knowledge in Geometry. Their study aspires to contribute on the knowledge based on what the
teachers know in making connection for mathematics. The results show that mathematical connection
is considered to be a primal characteristic. Moreover, future research studies should include precise
construction of assessments that clearly addresses the relationship between the mathematical concepts
and the topics, as well as value the creation and the learning of connections. However, there were
speculations on the methodology of the study as the questions assigned to the participants were not
specifically for mathematical connections. Additionally there are other cognitive processes involved in
solving the mathematical problems. Conversely, the study took a reductionist approach in utilizing
almost specific questions that requires mostly analogical transfers to solve, thus giving the study a
focus that contributes in valuing making mathematical connections.Sidney and Alibali [24] stated
people acquire new information within the context of their own prior knowledge. For example, when
students learn new mathematical concepts, they draw upon their existing knowledge of associated
mathematical concepts and practices. This exemplified that students have a starting point from which
they use to expand and gain more understanding when learning mathematics in sequences of lessons.
Consequently, one of the ways in establishing connections in mathematics is by guiding comparisons
through progressive alignments of similar problems [25]. Students might benefit greatly from
analogical transfer, indicating that identifying and applying from a structurally similar prior
knowledge if students were explicitly instructed to construct precise, relevant evaluations between
problems, which are highly similar in nature.

2. Method

The aim of this study is to investigate whether there is a connection or connections between the
lessons, in particular the mathematics content of the lessons of four competent Year 8 middle school
mathematics teachers in two different school settings in Brunei Darussalam. The use of the term
‘connection’ here refers to the explicit and implicit connections of the mathematical content between
the lessons in a lesson sequence. Moreover, the four teachers were characterized as competent based
on the mathematics teaching merits received from their respective school leaders and peers [26-32].
The two Brunei schools were selected based on convenient sampling. School X is an all girls high
school located in the heart of the city, Bandar Seri Begawan, catering toYear 7 to Year 11. On the
other hand, School Y is an elite co-educational high school located about six miles from the city.
School Y also caters Year 7 to Year 11, with an additional two years of Year 12.

The first teacher in School X (coded as X-T1) was a male teacher, who at the time of study,
possessed two years of teaching experience in mathematics. The highest level of formal education he
completed was a Bachelor degree with teacher training included (major field – Mathematics and minor
field – Physics). X-T1’s class was an express class (also called an accelerated or expedited class). The
students were admitted to an express class based on their ‘Year 7 End of Year examination’. The
second teacher from School X (X-T2) was also a male teacher but with six years mathematics teaching
experience at the time of this study. The highest level of formal education he completed was a non-
mathematics Bachelor degree without any teacher training included (major – Economics and minor –
Geography). However he upgraded his qualification with a Post-Graduate Certificate of Education
with a major field in Economics. The two female teachers in School Y (Y-T3 and Y-T4) also had two
years of mathematics teaching experience. The highest level of formal education Y-T3 and Y-T4
completed was a Bachelor degree with teacher training included (major – Mathematics and minor –
Physics for Y-T3, and for Y-T4 Physics was the major field and Mathematics as the minor).

The data collection was made by video recording continuous lesson sequences of the four Year
8 teachers. Table 1 shows the frequency of the video data. The two teachers from School X, X-T1 and
X-T2 had five recordings each, and from School Y, Y-T3 had four lessons while Y-T4 had six video-
recorded lessons in total.

| Teachers | Gender | No. of | Mathematics Topic(s) |
|----------|--------|--------|----------------------|
| X-T1     | Male   | 5      |                      |
| X-T2     | Male   | 5      |                      |
| Y-T3     | Female | 4      |                      |
| Y-T4     | Female | 6      |                      |

Table 1. Details of the mathematics lessons and the mathematics topics.
Interviews with the four teachers were conducted following their lesson observations. The venues chosen to conduct the interviews were, for X-T1 and X-T2, a quiet meeting room in School X, and for Y-T3 and Y-T4, an empty classroom in School Y. During the interviews, two video cameras were used; one video camera acted as a playback recorder to view the recorded lesson while connected to a television and the second video camera recorded the interview. Both the English and Malay Languages were employed for the interviews. As the interview commenced, each teacher chose a lesson from a selection of his/her video-recorded lessons. However, if he/she chose a single period lesson (25-30 minutes), then the teacher were required to select another lesson for discussion during the interview. Video-stimulated recall procedure was followed during the interview process [32], and the teacher was given the control of the video camera remote. This allowed the teacher to view selections of their chosen video-recorded lessons and by pressing the pause button, he/she can pause the lesson footage if he/she wishes to give comments on any of the important events within the lesson.

The data collected from the video recordings and interviews were transcribed and analyzed qualitatively in order to respond to the two research questions: 1) Are there any connections (similarities or patterns) between the mathematical content of the combined lessons between the four teachers? 2) Are there any connections between the mathematical content of the lesson sequences for each teacher studied (specifically on the content nature between the lessons)?

3. Results and discussion

Analysis of the data revealed various connections between the video-recorded mathematics lessons. There are two types of connections that will be reported. First to be reported will be from a broad perspective on how the mathematical content of the combined lessons between the four teachers were related, in other words, the commonalities across the combined twenty video-recorded lessons. Secondly was to focus in more detail on the connections of the mathematical content of individual lessons that belonged to one teacher, in particular X-T2 (specifically on the mathematical content nature between his video-recorded lessons).

3.1. The connection commonalities of the combined lessons

Although the teachers covered a variety of topics during the video-recording period, one common topic that emerged from these lessons was statistics. According to the ‘Mathematics Guide for a Scheme of Work’ for the Year 8 provided by the Curriculum Development Department, this topic was specified as ‘An Introduction to Statistics’ [33]. However, in the national Year 8 mathematics guide, the allocation of time as to when to teach the topic was not given. This meant that schools in Brunei...
were free to structure or organize when to teach certain topics within the school year. This was evidenced from the artefacts collected for this study, where Schools A and B had entirely different times dedicated to teach certain mathematical topics. Apart from X-T1, since he taught the express class and all five of his video-recorded lessons involved reviews, the remaining three teachers decided to teach the introduction to statistics topic to their students nearing the end of the school year. Hence, the first aspect of connection or similarity between the combined lessons of these three teachers is the topic ‘Statistics’.

The second aspect of connection commonalities that were found is that there exists a close similarity between the combined lessons of the two teachers in School Y. Besides School Y having their own timetable for teaching certain Year 8 mathematical topics, Y-T3 and Y-T4 also shared the same mathematics handouts, such as the lesson notes and the exercise questions. Despite these similarities, the teachers’ decisions regarding how to work on the exercise questions (or to demonstrate the worked solutions) with their students were different. For example, in the review lessons conducted by Y-T3 (T3L3 and T3L4) and Y-T4 (T4L6), both teachers distributed similar set of handouts that consisted of 20 review questions meant for preparing their students for the Mathematics Paper 1 in School Y’s End of Year examination. For Y-T3, she decided to provide her students with the worked solutions to 17 of the questions on the whiteboard. Y-T4 decided not to give the workings to any of the questions, instead she wrote only the answers (no worked solutions) on the whiteboard, and then instructed her students to group themselves according to their ‘pyramid group’ setting. Provided thus far are the accounts on the connections between the teachers collectively. Subsequently reported will be on the connections made by the individual teachers in each lesson sequence. In particular, examining the mathematical content of the lesson sequences of the four teachers.

3.2. The mathematical content connections for each four teachers

For this analysis, there were two teachers (X-T2 and Y-T4) who made visible connections by making reference to the content that was used in their previous lessons. However, the extent to which Y-T4 made the connections was not as significant as X-T2. For Y-T4, in her second video-recorded lesson (T4L2), she made references to the content of T4L1, which was on pie charts. In T4L2, she had to continue giving the examples related to pie charts, which are the examples to be given in T4L1. Lesson T4L1 was cut short because her students were required to assemble in the multi-purpose hall to attend a religious ceremony to commemorate the fasting month of Ramadan. The reason why there is a connection here is because Y-T4 needed her students to draw pie charts for the exercises she distributed. Her students were able to recollect how pie charts were drawn (as shown by Y-T4) in the previous lesson (T4L1) and apply it to the tasks given in T4L2. An example of an exercise on pie charts is given in Figure 1.

Six students have cats as pets at home. The following table shows the number of cats they have. Draw a pie chart for the data below.

| Yasmin | Jess | Allen | Amir | Rania | Sandy |
|--------|------|-------|------|-------|-------|
| 5      | 3    | 6     | 4    | 4     | 2     |

Figure 1. The exercise question on pie charts for T4L2.

These were the only visible connections that were found in Y-T4’s lessons, and, as should be clear, these connections were not intended, but arose for non-curricular reasons. For X-T1 and Y-T3, no references were made on the mathematical content linking the content of the topic taught to any of the lessons within their lesson sequences. For X-T1, all five of his video-recorded lessons involved ‘entirely review’ lessons (refer to Table 2). Although he connected some of the tasks within individual
lessons, he did not connect or refer the content of the given tasks to any of his video-recorded lessons, that is, he made no attempt to relate the content of a revision lesson to its preceding or following lesson.

**Table 2.** Details of the content nature in X-T1’s lessons.

| X-T1 Lessons | Category     | Details                                      |
|--------------|--------------|----------------------------------------------|
| T1L2         | All review   | Review on Algebra (Substitution in to formula) |
| T1L3         | All review   | Review on Algebra (Subject of formula)       |
| T1L4         | All review   | Review on Circles                           |
| T1L5         | All review   | *Review on Circles (repeat) & Review on Statistics |
| T1L6         | All review   | Review on Transformation                    |

*In T1L5, X-T1 instructed his students to continue the task on Circles given in T1L4.

Similarly for Y-T3, three of the four problem statements implemented as ‘making connections’ belonged in her ‘entirely review’ lessons (T3L3 and T3L4). Therefore, her discussions on the review tasks involved connecting tasks conducted prior to filming only. For the lessons T3L1 and T3L2 (see content details in Table 3), there were also no indications that content connection (or referenced the content of these lessons) was made to any of her video-recorded lessons.

**Table 3.** Details of the content nature in Y-T3’s lessons.

| Y-T3 Lessons | Category       | Details                                      |
|--------------|----------------|----------------------------------------------|
| T3L1         | Half review/Half new | Continued with Histogram (from the previous lesson) |
| T3L2         | Half review/Half new | *Introduced Pie Charts                      |
| T3L3 & T3L4  | All Review      | Review for End of Year Examination Mathematics Paper 1 |

*The students had encountered Pie Charts in the sixth-grade in their previous respective primary schools. Note that the students in School Y came from several different primary schools all over Brunei.

On the contrary, X-T2 made several connections by referencing specific examples from one lesson to the next. In fact, the visible connections he made were found in four consecutive lessons: T2L2, T2L3, T2L4 and T2L5. In T2L2, one of the exercises he showed to his students related to the uses of tally marks in counting and in constructing frequency tables (X-T2 followed the strategies suggested in the ‘Mathematics Guide for a Scheme of Work’ for Year 8). His instruction method involved calling on two students to write the answers on the whiteboard. The worked solutions (the frequency distribution table) are provided in Figure 2.

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**Please note how many cars passes School X from 3pm till 3.15pm on Friday.**

| Car Make | Numbers(by two students) | Tally(by X-T2) | Frequency |
|----------|--------------------------|----------------|-----------|
| BMW      | |||                   | 4           |
| Car       | Tally Marks | Frequency |
|-----------|-------------|-----------|
| Mercedes  | ||||         | 4         |
| Lexus     | |||||        | 6         |
| Jaguar    | ||||         | 4         |
| Kijang (Toyota) | |||| | 5 |
| Kancil (Daihatsu) | |||||| | 10 |

**Figure 2.** The frequency distribution table with tally marks (by two students and X-T2).

As shown in Figure 2, initially the students counted by putting 1,1,1,1 and so on (and X-T2 purposely did not inform the students the correct way of doing tally marks). As the lesson progressed, X-T2 informed them the correct way of writing the tallies. In his interview, he commented on this event and the comments are provided below.

X-T2: Yeah … Okay, actually the main idea was here. For example, frequency distribution table, and then … I think this is [referring to an event in his lesson on the TV screen] giving an example on observation to collect data.

Int.: See? [Referring to an event in his lesson on the TV screen].

X-T2: The one, one, one?

Int.: But they got the idea though.

X-T2: Ah, they got the idea … And then, it happened to be … I think it was in my other class, what they did was 1 plus 1, 1 plus 1, 1 plus 1, 1 plus 1 … like, I let them to make the mistakes first.

Int.: Yeah?

X-T2: And they’ll learn.

Int.: Do you wanna comment on it? [Denoting to his lesson event on the TV screen].

X-T2: Uh, yeah. Because I want them to know that, though this is acceptable, but it is not that appropriate. It’s kind of like an intro before I’m teaching them the … the real thing.

Int.: Do you think the students know about this tally mark? They can apply it to statistics.

X-T2: Yeah, yeah, yeah I guess … And then, by having the wrong thing and the right thing … umm … presented at the … at the same … at the same time, they can compare which one is the correct one, which one is the wrong one. So that’s why I … that’s the main reason why I … I wanted to see the mistakes first. So, it’s better off rather than it’s like, uhh … we show them the right thing and then only then we show them the wrong things lah. That’s my point here.

It is interesting that X-T2 purposely let his students make physical mistakes first in relation to the given tasks. It is interesting also that X-T2 was the only teacher to mention, and identify this particular event specifically in the interview. From the observations made of all the twenty video-recorded lessons, only X-T2 had this unique instructional style. For the other teachers, when their students responded incorrectly to a verbal mathematical question, the students were immediately informed of the correct answer. There were no elaborate explanations to discuss the students’ incorrect responses, other than praising and acknowledging the students for making the effort. In addition to the lesson activities in lesson T2L2, X-T2 also asked the students “What is the proper way for us in order to present this information? What can we do?” From these questions, he informed the students the
different types of representing data gained from the ‘make of cars’ data (the information portrayed in Figure 2), which were bar graph, pie chart, pictogram and line chart. Overall, X-T2 was confident that he reached the objectives of T2L2, which at the end of the lesson, the students should be able to: Understand the various forms of collecting data; Work on frequency distribution (tally marks); and Represent data collected based on the frequency distribution table. Meanwhile, in T2L3, he distributed a small piece of paper, which he called the ‘Drinks Survey’ to his students. The students’ responses to the drinks survey were collected and he again called two students to the front of the classroom. X-T2 made repeated reference to the content of the previous lesson (using tally marks in counting and constructing frequency tables) and instructed the two students to construct a frequency distribution table based on the results gained from the collected drinks survey data on the whiteboard. Figure 3 and Figure 4 illustrate the drinks survey and the related frequency distribution table respectively.

Please tick (✓) in one of the boxes below.

What is your most favourite drink?
- Coca-Cola
- Pepsi
- Fresh Orange
- Fresh
- Watermelon
- Soya Bean

| Drinks       | Tally Marks | Frequency |
|--------------|-------------|-----------|
| Coca-Cola    |             | 6         |
| Pepsi        |             | 6         |
| Fresh Orange |             | 5         |
| Fresh        |             |           |
| Watermelon   |             | 5         |
| Soya Bean    |             | 3         |

Total 25

Figure 3. The ‘Drinks Survey’ distributed in T2L3.

Figure 4. The frequency distribution table constructed by the two students in T2L3.

The two students were able to recollect the information given by X-T2 in the previous lesson (T2L2) in order to construct the frequency distribution table based on the drinks survey data collected from the twenty-five students in the class. Subsequently, X-T2 continued with T2L3 by introducing, explaining and drawing pictograms based on the students’ responses on the drinks survey. In T2L4, X-T2 again made used of the students’ responses on the drinks survey with the intention of representing the data into a horizontal bar chart. The students were also instructed to draw a vertical bar chart from the information gathered on the drinks survey. Meanwhile, for T2L5, he conducted the lesson in the school’s multimedia room. The room was equipped with a computer, a computer projector and an interactive whiteboard. X-T2 wanted to use the resources in the room with the purpose of showing his students the various forms of graphs (vertical and horizontal bar charts, pie chart and line graph), which he could produce, from the Excel program, using the same information (the drinks survey) repeatedly. In fact, X-T2 commented about this in his interview (provided below). Furthermore, in T2L5, the students were also shown how to determine the size of angles for a pie chart (based on information gathered on the drinks survey) on the interactive whiteboard.

X-T2 Since it is the last session so umm … I prefer to show the students to compare the various types of data based on one frequency distribution table.

X-T2 .... Ah, actually before this lesson, I did consult their ICT teacher and I asked him about their ability in … in … umm using the Excel program and then what the teacher told me was that they’ve used Excel before but umm … he is not sure whether the students are able to do their own graphs and so on. So what I did was, it’s like, I taught them
Based on the discussions here, X-T2 made visible significant mathematical content connections by firstly, making references on the use of tally marks in counting and in constructing frequency tables in T2L2, and again in relation to the construction of the frequency distribution tables using the drinks survey distributed in T2L3. Secondly, making references to the drinks survey he distributed in T2L3 in his subsequent lessons (T2L4 and T2L5). In addition, he also made references to the different types of representing data arising from the drinks survey (in T2L3) in the following lessons: T2L3 (pictograms), T2L4 (bar graphs) and T2L5 (bar graphs, pie chart and line chart). By making these mathematical content connections, X-T2 signifies the importance he attaches to the goal that the students will be able to visualize that the mathematical topic on statistics is not just represented by graphs, tables or figures or any single representational form. Furthermore, by making the appropriate connections between lessons he appears to believe that this will help students in employing the mathematical relationships involved while solving the problems in their lessons. In fact, the analysis made of X-T2’s lesson connections are consistent with the results where X-T2 had utilized the implementation of making connections in solving their mathematical problems to a greater extent in comparison to the other teachers.

From his interview, he also stressed that it was essential for all his students to see the benefit that real-life examples can bring to the topic of statistics. Evidently, in his lessons, although the students were quiet some of the time, however, in most parts, his lessons were lively and frequently entertaining and his students were actively involved in the class activities. Interestingly, he was the only teacher who incorporated real-life examples and real-life connections in his teachings. He mentioned in his interview that he enjoys creating stories in relation to his mathematics teaching, and his students found this stimulating, as these were useful in helping them to remember the connection in solving a mathematical problem in the future. According to Chong and Shahrill [34], “Solving real-world problems is one of the most significant cognitive and metacognitive process in understanding the real mathematics embedded in the real world” (p. 2). In Brunei, mathematics learning concerning non-routine or real-world problems in the real-world context settings was not typically exposed to the majority of our students [34-37]. Below are the extracted examples from X-T2’s interview.

X-T2: .... I prefer to teach uhh … I prefer to give examples, which are related to them, so that they are aware and they can think. And I feel that it is more interesting rather than just giving umm … examples based on what I read on the book … based on my own experience, which is not …
Int.: They remember this?
X-T2: Yeah, of course … And even that is one of my ways of recalling.
Int.: Okay.
X-T2: And then I prefer to do … to do things, which are not normal. For ex … for example, the examples are green, grey, black and orange. Because I know that girls, they would love pink like, purple and so on. But I prefer to use other … other … other colours and so on. So it’s like, they enjoy the class so that they can relax and they can learn.
X-T2: .... I normally make up storieslah [laughs].
Int.: I even remember what you did … just because it’s very interesting.
X-T2: Really? [Laughs] thank you … Ah … just making up … because my … the point is actually on the frequency distribution table … Kijang is … deer and Kancil is … mouse deer … the Penyaram … is the old traditional food in Brunei.
Int.: How did you relate that to statistics that day?
X-T2: I think it was on units, I guess … Say like, for example, supposed to be this 20 degrees or
The findings of X-T2’s lesson connections and the significance of his ‘making connections’ category in both task statements and solution types appear to support the work by Lampert [38], in which she investigated a different dimension of practice, that is, the teaching problems that arose in connecting content across lessons. X-T2 relied greatly on following the precise order of the curriculum delivery for the topic on statistics as was stated in the National Year 8 mathematics syllabus. Because of this, he was probably not consciously aware that his ‘deliberate’ lesson structuring may somehow contribute to his students’ mathematical learning experience. Unlike the other teachers, X-T2 consistently connected or made apparent references to several problem tasks among his lessons. More importantly, this is a significant instructional practice, which may not have been detected if only one lesson was video-recorded.

4. Conclusion
The comparisons of the individual teachers’ practices revealed how one particular teacher was noteworthy. According to the interview data collected from all four teachers, notably, only X-T2 mentioned the importance of making the relevant connections in his mathematics teaching. From the interview, X-T2 stressed that it was essential for all his students to see the connections of what real-life examples can bring to the topic of statistics. At the same time, he wanted his students to enjoy and learn mathematics from the enthusiasm he brought into his mathematics teaching. From the observations made, the same level of technique (the technique used to implement making connections problems) made by X-T2 was not detected in the lessons of the other three Brunei teachers. Then again, why is the least mathematically equipped teacher doing the most innovative teaching? A possible explanation that can be suggested is that, perhaps, since he did not have the relevant mathematical education background, he may have not seen the connection himself. We need to encourage teachers who are mathematical experts, not take for granted the connections that are obvious to them (and possibly, will be obvious to their students), and to include what X-T2 was doing, and to actually, very deliberately try to create the connections within and across their own lessons.

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