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Investigating capacity and mass using a problem-solving task: A lesson study with primary school students

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Abstract: This report presents a lesson study conducted with Year 4 and 5 students at Gozo College Ġużé Aquilina Primary and Special Unit Sannat, focusing on exploring the relationship between mass and capacity through problem-solving. The open-ended investigation is centred around a real-world scenario, which challenges students to investigate the common misconception that 1 litre always equals 1 kilogram. Through a hands-on approach involving different liquids and measuring tools, students collaborated in mixed-ability groups to compare, calculate and reason mathematically. The lesson integrated Universal Design for Learning (UDL), formative assessment and inclusive pedagogies to ensure all learners could participate meaningfully. Reflections from the teaching team highlighted key student misconceptions, strengths in collaboration and the value of structured inquiry for deepening conceptual understanding. The study illustrates how lesson study fosters professional collaboration, inclusive teaching strategies and responsive lesson design in support of the 21st century skills.

Keywords: Capacity; inclusive education; lesson study; mass; primary mathematics; problem-solving

Introduction

Lesson study (LS) is a collaborative professional development model that involves cycles of planning, teaching, observing and reflecting on a "research lesson". Originating in Japan, it has gained international prominence as a tool for improving teaching through teacher inquiry and collaborative reflection (Lewis et al., 2006; Takahashi & McDougal, 2016).

In this report, we examine how educators at Gozo College Ġużé Aquilina Primary and Special Unit Sannat implemented lesson study to address students' challenges in understanding mass and capacity and to foster inclusive and differentiated instruction. Measurement is a foundational domain in mathematics that bridges numerical concepts with real-world application. Despite its importance, primary students often struggle with understanding the relationship between mass and capacity due to abstract representations and a lack of contextual grounding (Pearn & Stephens, 2016). This research aims to investigate these concepts through a structured lesson study conducted in a Maltese primary school, with a particular focus on addressing the common misconception that 1 litre is always equivalent to 1 kilogram, as well as inaccuracies in reading measurement scales.

The lesson aligns with key curriculum goals by addressing measurement concepts, number operations and scientific inquiry. Students develop mathematical skills (e.g. measurement, scaling and calculation), scientific reasoning and collaboration. The combination of technology, real-world application and hands-on activities ensures that students remain engaged throughout the lesson.

This lesson effectively integrates assessment, inquiry-based learning, collaboration and self-reflection. It provides a well-rounded approach to teaching mass and capacity, ensuring students gain a thorough and practical understanding of the concepts while building critical thinking and problem-solving skills.

A key feature of this research is the focus on inclusion. Indeed, a variety of strategies, that align with Universal Design for Learning (UDL), were used to promote multiple means of representation and engagement (CAST, 2018).

The research lesson

From past item analysis exercises, it was evident that students were struggling in measurement topics particularly when it comes to reading scales. Moreover, teachers involved in this lesson study, confided their concerns about how to incorporate problem solving tasks, to address this struggle in their lessons. This lesson aims to deepen students' understanding of how capacity and mass are related, which is fundamental in real-life. In addition to this, students explore the fact that

volume and mass are not always directly proportional due to factors such as density.

The research lesson, which focused on a real-world problem of packing a suitcase within a weight limit, was used to introduce and explore the relationship between volume (capacity) and mass. Through inquiry, students investigated whether 1 litre of different liquids is always equal to 1 kilogram or not, discovering that this is not necessary always true due to differences in density.

The lesson was designed to focus on Learning Outcome 5.4.11, that is, "I can estimate, measure and compare lengths, masses and capacities". It also addressed broader goals, including the development of problem-solving skills, scientific reasoning and collaborative learning. The relevance and real-world application of the tasks incorporated in the lesson increased student engagement and promoted deeper understanding.

According to Dudley (2014), lesson study supports teaching improvement through shared inquiry and iterative lesson design. Year 4 and Year 5 teachers at Gozo College Ġużé Aquilina Primary and Special Unit Sannat collaboratively brainstormed ideas and designed a draft of the lesson in which they anticipated student misconceptions. During the process, they discussed ways how they intend to address these misconceptions. The iterative process, in the first cycle of the lesson study, allowed for refinement based on classroom observations and a reflective discussion before the second and final, teaching of the research lesson.

After the lesson, teachers used their observations and student reflections to evaluate the outcomes and success of the lesson, identify areas for improvement and adjust instructional strategies accordingly. This reflective practice exemplifies the cyclical nature of lesson study and its capacity to foster a professional learning community (Takahashi & McDougal, 2016).

The lesson study context

The school

Gozo College Ġużé Aquilina Primary and Special Unit Sannat is an inclusive school catering for students from kindergarten to Year 6 and up to age 22 in its Special Unit. The school emphasises personalised

education, with a vision rooted in inclusive pedagogy, community collaboration and the development of lifelong skills. Recognizing the diverse learning needs of its students, particularly in mathematics, the school chose to explore the use of lesson study to improve teaching around complex measurement concepts. The goal of the lesson study team was twofold, to:

1. improve instructional strategies in measurement and
2. develop a sustainable model of collaborative professional learning.

The students

Students from Year 4 and Year 5 were selected for this research lesson because, at this stage, mathematics introduces more advanced concepts, often making it challenging for students to grasp foundational ideas. Additionally, the curriculum at this level places significant emphasis on developing problem-solving skills and other higher-order thinking abilities, which can present further complexities for learners. Recognizing the diverse range of mathematical abilities within this age group, the goal is to design lessons that address varying levels of understanding and learning needs.

This multi-levelled lesson adopts an inclusive approach, enabling every student to actively engage with the material, achieve comprehension and find enjoyment in the learning process. By creating a supportive and adaptable environment, the lesson aims to foster confidence, encourage participation and inspire a deeper appreciation for mathematics in all students.

The team members

Name	**Role at school**	**Role in lesson study**
Jeanelle Attard	Head of Department (Maths)	Facilitator
Maria Xuereb	Maths Support Teacher	Facilitator
Nadia Cremona	Teacher	Team member
Mario Mifsud	Teacher	Team member + delivered the lesson trial (1st cycle) and actual lesson (2nd cycle)
Joanne Ghirxi	Deputy head of school	Team member

The lesson study process

The meetings

Date	Points discussed
24/10/2024	• Topic chosen is Capacity (level 5) • Reading and interpreting scales with different intervals • Learning outcome: I can estimate, measure and compare lengths, masses and capacities
28/10/2024	• Agreed on the pedagogy namely: inquiry-based learning, differentiated prompts/tasks and AfL strategies • Venue chosen is the school hall for adequate space since there are around 40 students working in groups • A period of 1 month to input ideas/activities in a shared online folder with a template of the first draft of lesson plan
25/11/2024	• The use of mentimeter instead of KWL chart • Being critical about different real-life scenarios: the one chosen is the luggage task • Estimated time taken for students to complete the different tasks • Brainstormed tasks involving the estimation of liquid in different jars. In addition, culturally responsive activities (e.g., olive pressing/cheese lets making)
04/12/2024	• Develop questions and anticipate students' answers • Plan graded questions based on the Bloom's Taxonomy pyramid
10/12/2024	• Finalise lesson plan during online meeting • Compile a list of things needed for the lesson

The lesson and problem-solving task

Aim of the lesson: Understanding the concept of capacity and mass, exploring the connection between volume and weight and applying measurement skills.

The lesson integrated constructivist, where learners construct knowledge through active engagement (Vygotsky, 1978) and the use of inclusive pedagogies. By utilizing real-life scenarios and hands-on activities, the lesson engaged students in exploring scientific and mathematical principles.

The focus on the 4Cs, that is, critical thinking, communication, collaboration and creativity, further emphasized 21st century learning goals (NEA, 2012). The group tasks invited students to engage in peer teaching and problem-solving, while the final group discussion fostered metacognitive reflection and critical thinking.

Formative assessment was embedded throughout the lesson. The initial Mentimeter task allowed teachers to assess prior knowledge and misconceptions. In addition, visual aids such as "Peter Litre" and "Mrs. Kilograms" supported conceptual understanding. During the lesson, students worked in small groups, using bottles of different volumes (100ml, 250ml, 500ml), measuring cylinders and digital scales to investigate the mass of different liquids. Teachers observed and recorded student interactions, providing real-time support. The lesson concluded with a group reflection and self-evaluation activity, supporting metacognitive skill development and encouraging students to take ownership of their learning (Dweck, 2006).

In working through problem-solving, students will be required to think critically as they make connections between capacity and mass. They will be active in their learning while collaborating with group members on how to go about calculating the mass of the different liquids (deducting the weight of the empty bottle, multiply the sample amount by 2 or 4 depending on the capacity of the empty bottle, reading intervals, reading and interpreting the scale on the measuring tools…).

Students' task sheet

Step 1: What are we investigating?

_____

_____

Step 2: My Prediction

What do you think will happen?

I predict that...

_____

_____

_____

Step 3: My Conclusion

What did you observe? Was your prediction correct?

I learned that...

_____

_____

_____

Step 4: Success Criteria

Tick the boxes that match your work:

☐ I made a clear prediction.

☐ I can estimate and measure accurately masses and capacities.

☐ I can use appropriate tools to measure masses and capacities accurately and use the correct units of measurement (e.g. kg, g, ml, L).

☐ I carefully observed and recorded the results.

☐ I wrote a conclusion based on what happened in the investigation.

The lesson plan

Phase 1: Introduction	
How will the lesson be introduced? What will you say and/or do to get them interested?	The teacher puts a suitcase on display. S/he presents the following scenario as an introduction to provoke discussion. **"A suitcase is overpacked. It's bulging but still under the weight limit. Does it have more mass or more capacity?"** In pairs, students will have the opportunity to discuss this statement with their neighbours and then report to the whole class. The teacher should lead this discussion without saying whether the statements given are true or false. Following this, the teacher instructs each pair to input the similarities and differences between mass and capacity using 'Mentimeter' app on their tablet.
What difficulties might students encounter?	1. Students struggle to identify differences/similarities between capacity and mass. 2. Students could make use of interchangeable language such as "this luggage is heavy" when referring to both its mass and the amount it can hold (capacity). Students could also associate mass to solids only and capacity to liquids only.
How do you intend to address these difficulties?	1. Teacher prompts students by providing sentence starters to reflect on: • the metric units • instances when they are used • tools needed to measure them • are they directly proportional? For example, 'Is the greater the mass of the luggage, the greater its capacity?' 2. The teacher reports to the whole class the students' responses and clarify any misconceptions. To prompt students to come up with the conclusion that 'Mass and capacity are not directly proportional', the teacher could present this example: "A glass jar filled with feathers and the same type of jar filled with marbles. Do they have the same mass? Do they have the same capacity? Explain why".

Phase 2: Students' work	
How will students work? Will they be involved in individual work? Or will they be asked to work in pairs or within a small group of 3 or 4 students? Explain how this will be done.	The teacher presents a real-life scenario where Megan is packing her luggage for a weekend abroad. This sets the context for the lesson's main investigation. **Story**: Megan is packing her belongings into a suitcase for a weekend abroad. She can carry a maximum mass of 20kg in her luggage. Along with her clothes, she packs liquid bottles containing toiletries. Megan wonders how much liquid she can take with her. She reasons that since 1 kilogram is equal to 1000 grams and 1 litre is equals to 1000 millilitres, then 1 litre of liquid must have a mass of 1 kilogram. Investigate whether Megan's reasoning is always true, sometimes true, or false and explain why. **Challenge**: Megan needs to take hair oil, shampoo and micellar water for face hygiene with her in the luggage. She has got 100ml, 250ml and 500ml bottles to pour liquid in them. Calculate the mass of 1 litre of each of the three liquids. Students are prompted to explore Megan's hypothesis: Is 1 litre of liquid always equal to 1 kilogram of mass? **During the hands-on activity**: • Students work in small groups of not more than 5 students to measure liquids accurately, read scales with different intervals and calculate the mass of three different liquids provided. • To introduce an additional challenge, students are only provided with 100ml, 250ml and 500ml bottles. They must use these to measure and pour liquids and then apply their number operation skills to calculate the mass of 1 litre of each liquid. • Throughout this activity, the teacher assesses students' accuracy in measurement and their ability to perform calculations.
What difficulties might students encounter with the set task/s as they start working on it?	1. Students may face difficulties when reading and interpreting the different intervals on the different measuring cylinders. Students might do a parallax error (misread the liquid level when measuring due to the angle of viewing). 2. Another area of concern is students' struggle when converting between units and carrying out decimal calculations. 3. Uneven participation among group members.

How do you intend to address these difficulties? What kind of help do you intend to provide?	1. Allow students to practice measuring liquids before the main activity. 2. Provide students with supportive tools that include conversion chart and anchor posters (Peter Litre and Mrs Kilograms), to help in calculating and conversion of units. 3. To facilitate group dynamics, the teacher encourages students to assign clear roles for all students to participate effectively.
Phase 3: Summary and closure	
How do you intend to bring the lesson to a closure?	After investigating with the three different liquids, students gather data and report back their findings. They could compare their hypothesis with the drawn conclusions. This could lead students' curiosity to learn more about density and how it could affect the relationship between the mass and capacity of the different liquids. Each group discusses the process taken to come up with a conclusion. They also need to justify the conclusion drawn through critical thinking within the whole group.
What difficulties might students face during this phase of the lesson?	1. Students might struggle to organize their ideas and explain their reasoning in a coherent way. 2. Some students may find it difficult to connect the evidence gathered to their conclusion or may misinterpret the data. 3. Dominant voices in the group may overshadow quieter students, or groups might struggle with collaboration.
How will you try to address these difficulties?	1. Provide sentence starters based on bloom's taxonomy pyramid to guide their explanation (e.g., "I think this because…"). 2. Encourage students to revisit their notes or sources and use guiding questions to help them see connections. 3. Assign roles (e.g., speaker, note-taker, timekeeper) to ensure equal participation and maintain focus.

Post-lesson reflections

- Students worked well in mixed ability groups. Most of them were engaged, followed clear instructions and participated fully,
- Students enjoyed themselves during the hands-on activity and guided each other to read and interpret the different scales on the different measuring cylinders,
- Students had a misconception about capacity, as they associated it only with liquids. Therefore, greater emphasis should have been placed during the lesson introduction,
- While students were presenting their method of calculation, there were two different methods; in the first method students deducted the mass of the empty bottle from the total mass of bottle and liquid before multiplying the mass of liquid by 2/4/10 to make it equivalent to 1L. In the second method, students multiplied the total mass of bottle and liquid by 2/4/10 and then they deducted the mass of 1 empty bottle, without realising that they should have deducted 2/4/10 of such bottles. During the post-lesson, the teacher decided that this issue will be further explained during follow up lessons.

Main takeaways

The lesson revealed several challenges typical in inclusive classrooms, including:

- *Misconceptions about measurement*: Students often assumed a direct correlation between volume and mass. Teachers addressed this through guided questioning and hands-on comparison.
- *Collaborative dynamics*: Uneven participation was mitigated by assigning roles (e.g., timekeeper, recorder, presenter).
- *Mathematical operations*: Some students struggled with scaling measurements and reading intervals. Support materials such as conversion charts and practice exercises were provided.

This case demonstrates the potential of lesson study to enhance both teacher practice and student learning in inclusive settings. Through collaborative planning, observation and reflection, educators developed a lesson that was responsive, engaging and pedagogically sound. The iterative nature of lesson study encouraged continuous improvement and professional growth.

This collaborative research reflects the flexibility and responsiveness of lesson study and confirms that differentiation is essential for inclusive education (Perry & Lewis, 2009). Indeed, the integration of UDL principles, constructivist methods and 21st century competencies indicates that lesson study can be a powerful vehicle for inclusive and effective mathematics instruction. Future iterations could explore connections to scientific concepts like density more explicitly, extending the interdisciplinary potential of the approach.

The lesson study team has learned the importance of addressing students' misconceptions early in the lesson, using concrete examples to deepen their understanding. They also recognized the value of collaborative planning and reflection in enhancing teaching strategies. Moving forward, the team aims to continue refining their approach by incorporating more hands-on activities, real-life applications and student discussions. Additionally, they plan to engage in ongoing professional development and peer observations to further improve lesson delivery and student learning outcomes.

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Huawei Technologies

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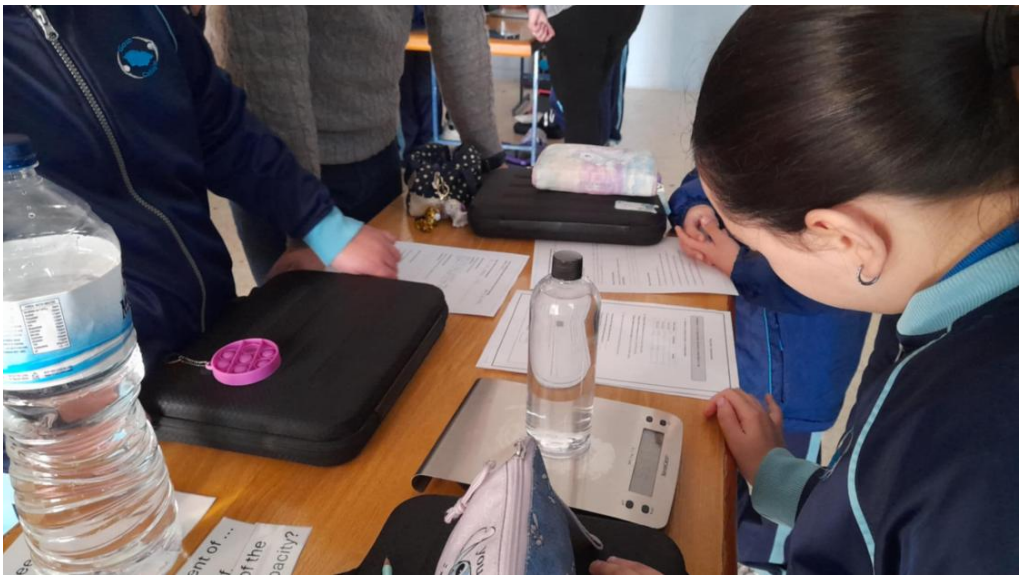
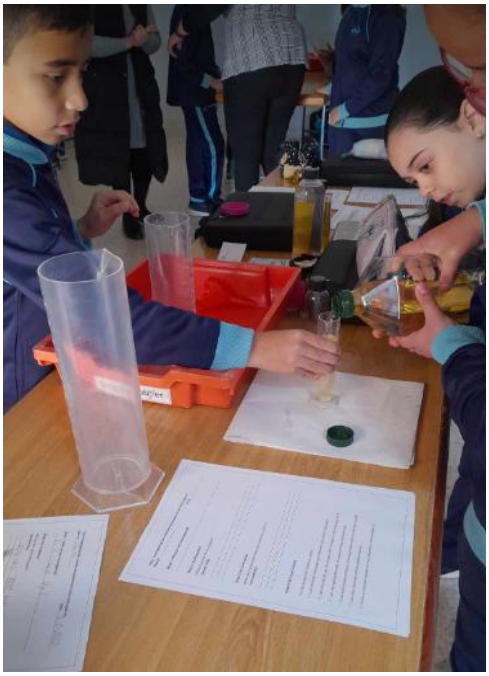
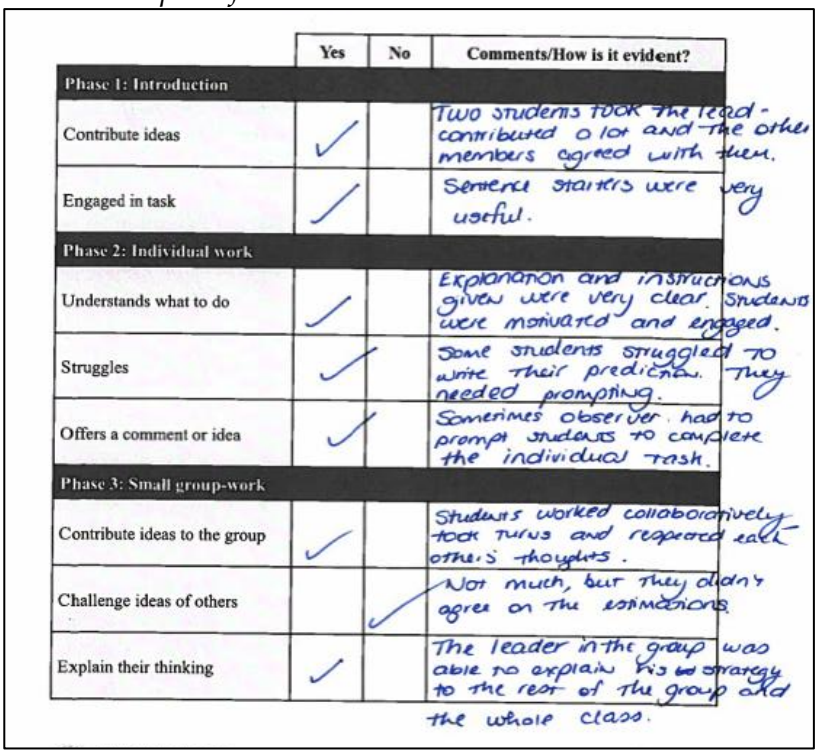
Appendices

Appendix 1 – The lesson in pictures

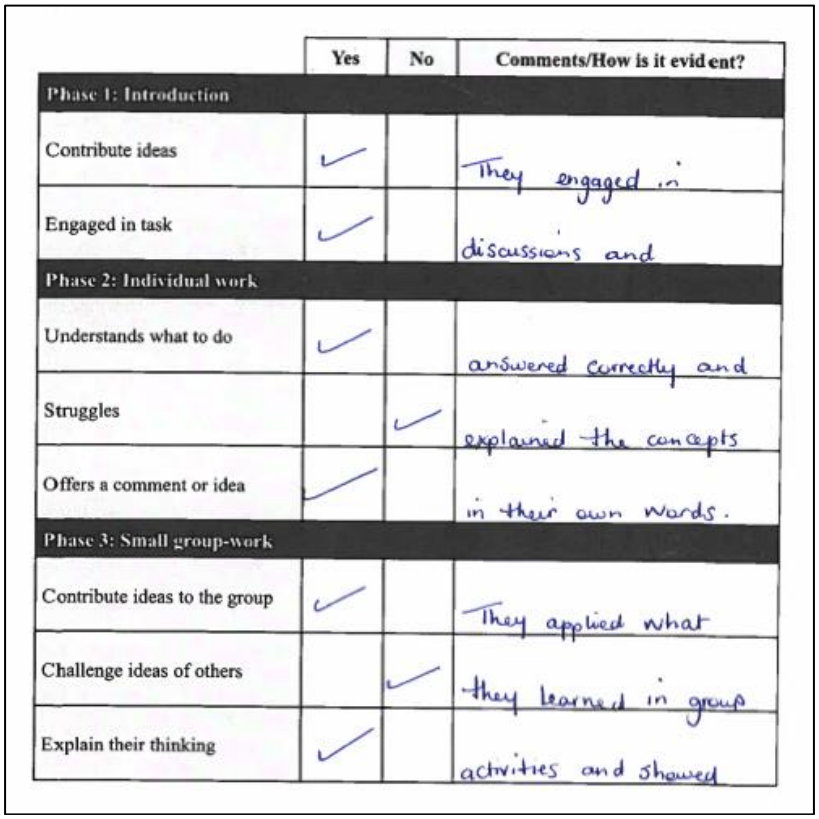




Appendix 2 – Examples of recorded data in lesson observation sheets



	Yes	No	Comments/How is it evident?
Phase 1: Introduction			
Contribute ideas	✓		Two students took the lead - contributed a lot and the other members agreed with them.
Engaged in task	✓		Sentence starters were very useful.
Phase 2: Individual work			
Understands what to do	✓		Explanation and instructions given were very clear. Students were motivated and engaged.
Struggles	✓		Some students struggled to write their prediction. They needed prompting.
Offers a comment or idea	✓		Sometimes observer had to prompt students to complete the individual task.
Phase 3: Small group-work			
Contribute ideas to the group	✓		Students worked collaboratively took turns and respected each other's thoughts.
Challenge ideas of others		✓	Not much, but they didn't agree on the estimations.
Explain their thinking	✓		The leader in the group was able to explain his strategy to the rest of the group and the whole class.



	Yes	No	Comments/How is it evident?
Phase 1: Introduction			
Contribute ideas	✓		They engaged in
Engaged in task	✓		discussions and
Phase 2: Individual work			
Understands what to do	✓		answered correctly and
Struggles		✓	explained the concepts
Offers a comment or idea	✓		in their own words.
Phase 3: Small group-work			
Contribute ideas to the group	✓		They applied what
Challenge ideas of others		✓	they learned in group
Explain their thinking	✓		activities and showed