OBSERVING THE MICROBIAL WORLD: STUDENT EXPERIENCES

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Students carry many preconceived notions about microorganisms. Exploring puddles of rainwater provide an opportunity to reveal these notions and help students appreciate the diverse microscopic life-forms present around them. Can teachers use such explorations to offer students a first-hand experience of the process of science, and help develop their scientific skills?

Have you ever observed water in the pits and puddles that appear after the rains? Each of these temporary collections of rainwater act as micro-ecosystems, supporting many different tiny life-forms that vary from place to place and season to season. Such observations of the natural world are not only vital to the practice of science, but also to its teaching and learning in the classroom. In fact, an interest in science often begins with observations of our immediate surroundings that engage our curiosity.

To encourage students to study such micro-ecosystems in and around their schools, we designed a learning unit comprising a series of simple, hands-on activities and shared it with teachers from various schools (see **Box 1**). This article was derived from the classroom experiences shared by of one of the teachers with 20 students of Grade VIII.

Students' preconceptions about microorganisms

To explore students' prior knowledge about microscopic life-forms, their prevalence in our surroundings, and concepts like 'life' and 'dormancy', they were asked to observe as many puddles as they could find in and around the school. To gain insight into their ideas about microbes, the students were then asked to respond to the following questions:

(a) The existence of microorganisms

All the students showed an awareness of microscopic life forms by responding in the affirmative to the question **'Do you think there is life in those puddles?'**. Some offered reasons: *"...because they (puddles) can provide all necessary living elements to the microorganisms"*. Interestingly, some students expressed the belief that millions of microorganisms could exist in puddles as small as 10 cm in diameter (see **Fig. 1a, 1b & 1c**).

Box 1. Examples of links to curriculum:

A review of the Grade VIII NCERT textbook showed at least two chapters (2 and 8) that are directly linked to the aims, concepts and activities that we explore in this learning unit.

- **Chapter 2:** 'Microorganisms: Friend and Foe' includes two activities (2.1 and 2.2) that are intended to enable a hands-on approach to observing microorganisms from soil samples or pond water. This learning unit was developed by extending these activities to help middle school students develop the observational, recording, drawing, describing, and measuring skills required to learn science.
- **Chapter 8:** 'Cell Structure and Function' has an extended learning section about the use of microscopes. This learning unit provides a direct opportunity to observe microorganisms under a microscope.

(b) Sources of microorganisms

When asked **'Will there be life forms in a dry sample (for e.g., dry soil)? If yes, where do they come from — soil, water, or air?'**, most students expressed the belief that even dry soil could contain microorganisms. Many of them justified this by sharing that microorganisms were known to survive *"in any type of climatic conditions, from marshy lands to dry deserts"*. Most students believed that air was the primary source of microorganisms (see **Fig. 1d**). For example, many of them expressed beliefs like: *"if soil is dry there will be no water in it, only air can be there"*, implying that any microorganisms in a dry soil sample would come from the air. Some students mentioned that soil and water could also act as sources of microorganisms (see **Fig. 1e**). Interestingly, many students who believed that air was a source of microorganisms did not believe that water could be a source too.

(c) Survival/dormancy

Responses to the question **'When the puddle or a wet soil sample dries up, what do you think happens to the life forms living in it?'**, revealed conflicts and confusion in students' understanding of the factors necessary for the survival of microorganisms. Many students believed that water was essential for the survival of microorganisms, and its absence would kill them (see **Fig. 1f & 1g**). This was reflected in responses like: *"If there is no water then the microorganisms will die"*, or *"When the soil sample dries the microorganisms will die"*. Other students believed that different microorganisms would respond to the lack of water in different ways. For example, some believed that: *"When the soil sample dries... the number of microorganisms will decrease in number"*. A few others suggested that: *"When the wet soil sample dries up... some microorganisms will [be] left over as we know that microorganisms can live in every climate"*. These responses reflected some understanding about the dormancy condition (see **Box 2**). One student expressed the belief that the survival of microorganisms in dry soil would depend on their tolerance to drying due to heat (from the sun): *"When the wet soil sample dries, the life forms such as bacteria can exist there. But some microorganisms can't resist the temperature"*. Another student expressed the surprising belief that *"When the wet soil samples dries the organisms that require water may die but the other organism may live in it"*. This student seemed to believe that some microscopic life forms did not require water to survive.

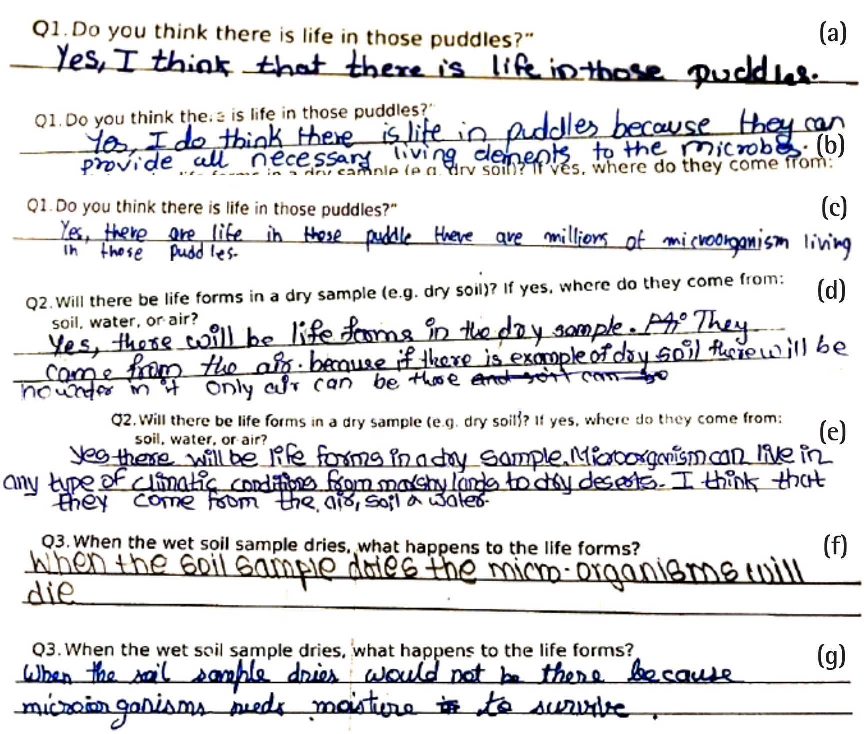


Fig. 1. Student responses based on their preconceptions about microorganisms.

Box 2. Dormancy in microorganisms:

Microorganisms have a higher degree of physiological tolerance and can undergo a reversible state of low metabolic activity. This ability, known as **dormancy**, helps them overcome unfavorable environmental conditions. Dormancy not only protects microorganisms from death and possible extinction, it also plays a role in ecosystem stability and biodiversity.

Many students seemed to associate the presence or absence of water as the only criteria essential for the survival of microorganisms. While students in this grade are usually aware of hibernation in reptiles and mammals, they have not yet developed an understanding that microorganisms can be alive even in dormancy condition. This may be because science textbooks do not engage with the dormancy of microorganisms at the conceptual level. Even if they did, students may find it difficult to relate the concept to life at a microscopic level. This simple exercise can help students understand the dormancy condition in microorganisms, and connect it to hibernation and aestivation in larger animals. It can also help establish links between microorganisms and concepts like the environment, ecosystem, diversity, survival, and evolution.

(d) Microorganisms in our surroundings

When asked **'Will there be life forms in a drop of clear water? Why do you think so?'**, many students stated that this was possible, *"because the clear water provides all the necessary elements of the microorganisms"*. Some students suggested that microorganisms could multiply rapidly in water, and would therefore be quite numerous. Others expressed the belief that the microorganisms or bacteria in clear water would be beneficial to us. Some students were less certain, and wondered about ways of confirming this possibility. This was evident in responses like: *"microorganisms cannot be seen with naked eye. Then how we can see that there are life forms in drop of water or not"*. Or, *"I don't think so because if the water is clarified and it is clear microorganisms are also removed but some microorganisms may be living in that drop of water because we cannot see them"*.

Encouraging microscopic observations of microorganisms

To put their ideas to test, students were asked to observe soil and water samples under a microscope, and use notes and drawings to record details of any life forms they spotted (see **Box 3**).

Students observed and described the samples under two magnifications (10X and 45X) of the microscope (see **Box 4**). Their meticulous records of these observations describe the colour, shape, size, and location of microorganisms in the visual field. For example, responses regarding colour mention blue-, black-, purple-, and violet-coloured microorganisms. Similarly, those regarding shape mention irregular, thread-like, elliptical, and circular forms of microorganisms (see **Fig. 2a, 2b & 2c**).

In response to the question **'Do you think the objects you see under the microscope are living or non-living? How can you tell?'**, all the students expressed the belief that motile microorganisms were living, and immotile ones were dead (see **Fig. 2d, 2e & 2f**). Students were also encouraged to collect soil and water samples (like samples of drainage water, tap water, tank water, and

Box 3. Facilitating student observations under the microscope:

Teachers may need to start this task by:

- Familiarizing students with a compound microscope, its parts, and the function of each part. This can be coupled with the activity of observing slides.
- Helping students in preparing slides and observing them under the microscope. This may involve help with seeing through the eyepiece, focusing the objective lens, aligning the slide, adjusting the light, and calculating the total magnification at which the slides are observed, etc.

Box 4. Observe, describe, draw, and record microorganisms:

Guidance for students:

- Prepare a slide by placing a drop of the sample on the slide. You may cover it with a cover slip.
- Observe the slide under the microscope. Explore all the areas of the slide, and try to record as many different objects that you can see.
- Change the magnification, and try to see the same objects magnified. Carefully observe any living organisms in the visual field, and note their relative sizes.

Questions for student worksheet:

- What do you observe under the visual field of the microscope? Describe it in your own words in terms of their number, size, shape, color, motility, etc.
- Do you think the objects that you see are living or non-living? Why do you think so?
- Draw what you observe on a plain or graph paper (to be provided by the teacher). You can draw by first creating a circle of your visual field and using the inside of the circle for drawing almost all the microorganisms that you observe as per their position, size, shape, color, etc.
- Change the magnification of the microscope, and draw the same microorganisms at various magnifications on a plain or graph paper. You can follow the same method of drawing inside the circle of the visual field.
- Try to identify the life forms that are being observed. Use the **Field Guide** (to be provided by the teacher) to identify the life forms that are closest to what you have observed on the slide.
- Write down the names of the life forms that you find to be a close match with that of the key.

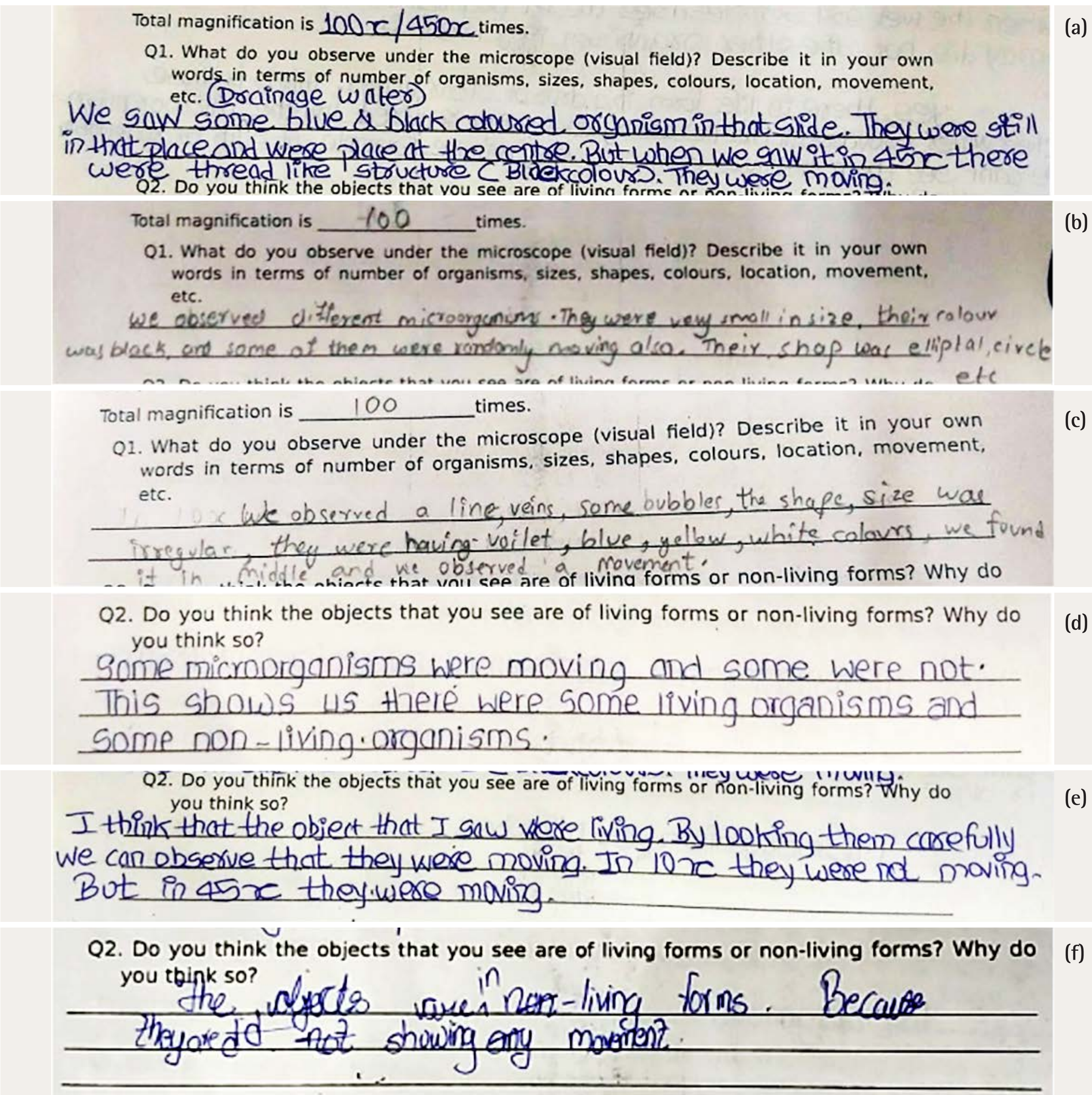
Suggestions for teachers: Once students have recorded their observations, they could be encouraged to look at each other's slides and compare notes, drawings etc. This could be followed by a class discussion on student observations, with particular emphasis on the kind of variety they can spot among life forms from different samples.

pond water) from different places in and around their school and homes (see **Box 5**). This activity offered students the opportunity to appreciate the diversity of microorganisms that inhabited their surroundings. It also made this study more exciting as students were able to relate the source of their samples with their observations under the microscope.

Box 5. Guidance for students in locating and collecting samples from their surroundings:

Locate some puddles filled with water at your doorstep, at home, or in school. If the location you choose is wet, collect a water sample with a spoon and place it in a container. If the location you choose is dry (i.e., if there is no puddle), then collect a soil sample with a spoon and place it in a container. Later, add a few drops of water, and leave undisturbed to allow the soil to settle down.

Label the collected samples with your name; the date, time and location of collection; and mention whether the sample is dry or wet.


(a)
Total magnification is 100x/450x times.
Q1. What do you observe under the microscope (visual field)? Describe it in your own words in terms of number of organisms, sizes, shapes, colours, location, movement, etc. (Drainage water)
We saw some blue & black coloured organism in that slide. They were still in that place and were place at the centre. But when we saw it in 45x there were thread like structure (Black colour). They were moving.

(b)
Total magnification is 100 times.
Q1. What do you observe under the microscope (visual field)? Describe it in your own words in terms of number of organisms, sizes, shapes, colours, location, movement, etc.
we observed different microorganisms. They were very small in size, their colour was black, and some of them were randomly moving also. Their shap was elliplal, circle etc

(c)
Total magnification is 100 times.
Q1. What do you observe under the microscope (visual field)? Describe it in your own words in terms of number of organisms, sizes, shapes, colours, location, movement, etc.
We observed a line, veins, some bubbles, the shape, size was irregular, they were having voilet, blue, yellow, white colours, we found it in middle and we observed a movement.

(d)
Q2. Do you think the objects that you see are of living forms or non-living forms? Why do you think so?
Some microorganisms were moving and some were not. This shows us there were some living organisms and some non-living organisms.

(e)
Q2. Do you think the objects that you see are of living forms or non-living forms? Why do you think so?
I think that the object that I saw were living. By looking them carefully we can observe that they were moving. In 10x they were not moving. But in 45x they were moving.

(f)
Q2. Do you think the objects that you see are of living forms or non-living forms? Why do you think so?
The objects were in non-living forms. Because thy are dd not showing any movement.

Fig. 2. **Students' descriptions of microorganisms from the soil sample as seen under a microscope.**
Credits: Meena Kharatmal.

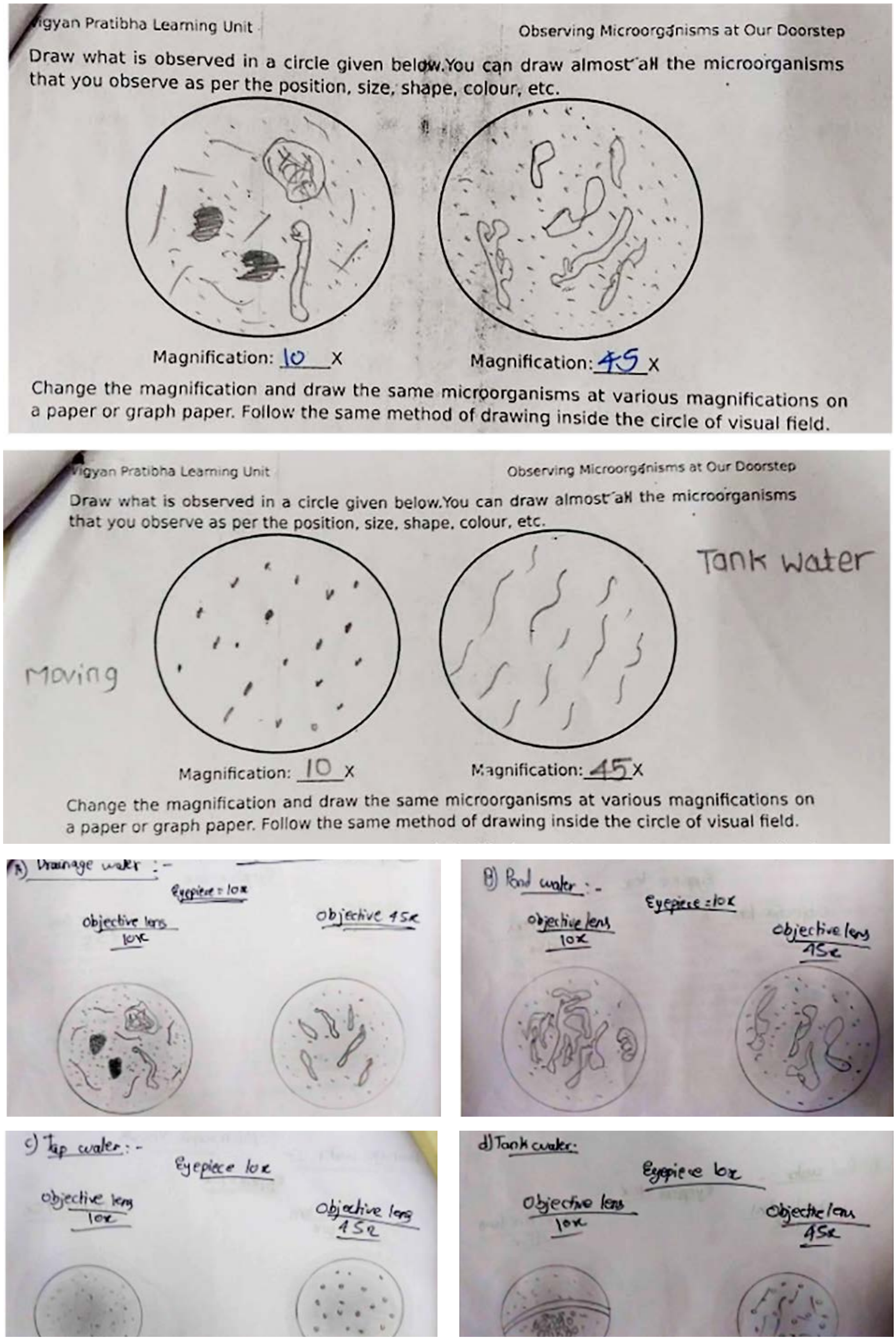


Fig. 3. Students' drawings. These reflect the microbial diversity seen in samples collected from a drain, pond, tap, and tank. Students' drawings of microorganisms as viewed under the two magnifications are also quite distinct from each other.

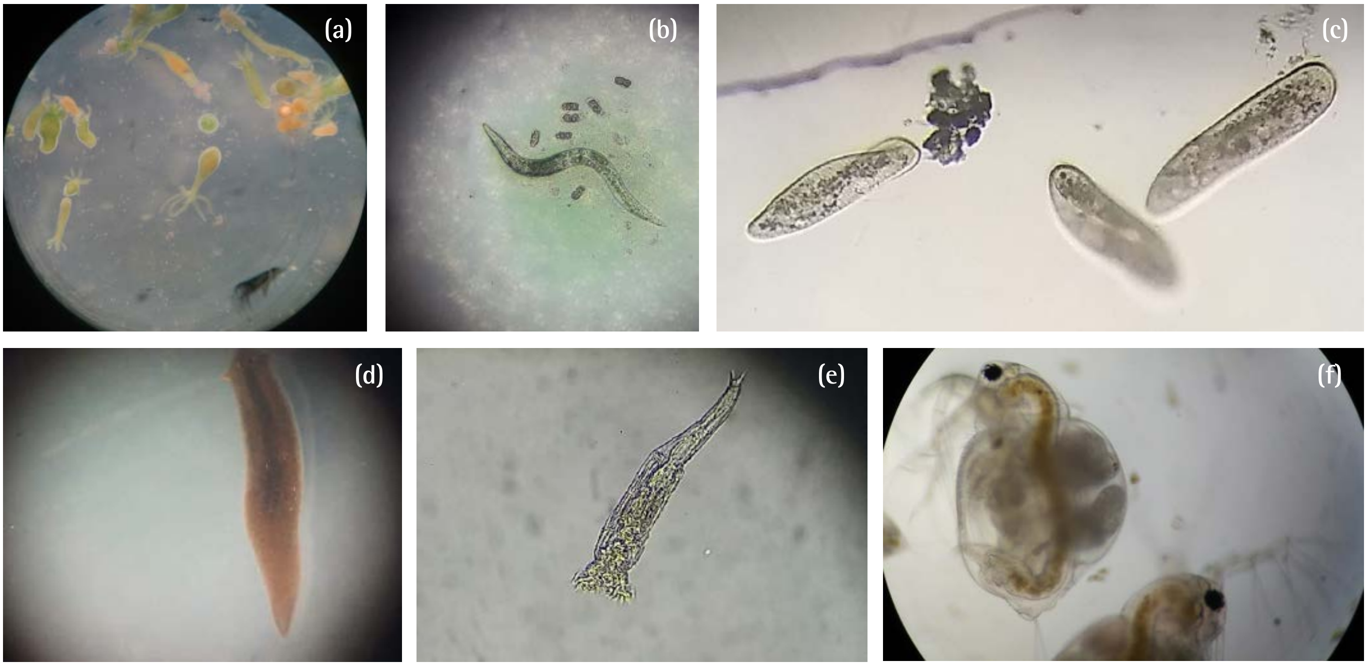


Fig. 4. Some of the life-forms observed in the soil sample: (a) Hydra **(b)** Nematode **(c)** Paramecium **(d)** Planaria **(e)** Rotifer **(f)** Water flea.

Students were asked to use drawings to record their observations of the samples (see **Fig. 3**). Encouraging students to draw what they have seen under the microscope rather than copying a diagram from a textbook can strengthen their powers of observation. Some students even managed to convey movement through their drawings. Finally, students were asked to try identifying some of the microorganisms in their samples by matching their own drawings with those in their textbook and in a key that we provided (see **Field Guide**). They were able to identify microorganisms like paramecia, rotifers, nematodes, and spirogyra more easily than others (see **Fig. 4**). Interestingly, these microorganisms are common examples in their textbook.

To help them appreciate how tiny microorganisms are, students were asked to measure the size or length of some of the life forms that they had observed in the visual field of the microscope. Many science labs use a micrometre slide to measure the size or length of objects under the microscope. For school labs that do not have a micrometre slide, we shared a simple method to measure size using a transparent ruler (see **Box 6**). Since students understand measurements of size in meters, centimetres, and millimetres, we encouraged them to use conversions of these units to estimate the size of microorganisms.

The students' worksheets on measurement showed that they found the estimation task difficult to understand and work out. One key challenge was related to the conversion of units, like millimetre to microns. Students also tended to divide the entire visual field size by the number of objects that they could see to get the size of each object. Since objects were not located at uniform distances in the visual field, this method offered an estimate of the size of visual field rather than the size of individual microorganisms. It is possible that students may need more attention and time to understand this calculation, its units of measurement, and method of conversion, etc.

Box 6. **Measurement and estimation of microbial size:**

Guidance for students:
Place a transparent ruler (mm divisions) under the objective lens (10X) of the microscope, and observe through the eye-piece. We can see two divisions of the ruler within the visual field. Since the two divisions of a scale are 1 mm apart, we know that the visual field is 1 mm (or 1000 microns) in diameter. We can use this measurement to estimate the relative size of the microorganisms that we observe under the microscope.

Questions for student worksheet:
Visual field = ... mm = ... microns

Size of microorganisms observed = ... microns.

Suggestions for teachers:
Teachers may need to calibrate the microscopes used for the study, and introduce students to the simple conversion of 1 mm = 1000 microns. They may also need to guide students in estimating sizes through this method.

Parting thoughts

This pedagogical learning unit is aimed towards drawing out prior beliefs of students regarding the existence, source, and dormancy of microorganisms. This will help students connect concepts related to microorganisms from the science curriculum with the diverse microorganisms found in their own surroundings.

It also offers them the opportunity to develop scientific skills like observing, hypothesising, drawing, and measuring. Often, students depend on the teacher to provide correct answers to all questions raised in the classroom. When this happens, most students tend to copy or replace their own response with that of the teacher's. The exercises in this unit have been designed to help students think, reason, and explain their observations in their own words. Hence, we request teachers to avoid offering clues or answers.

It is worthwhile to emphasize the importance of the drawing activity. Often, when asked to express their observations in words, students tend to use descriptions that are based on teacher inputs. On the other hand, student drawings reflect what they think they have actually observed. Drawing not only helps students develop their power of observation, it also encourages the habit of recording their observations.

Student records and collections of microorganisms from different microecosystems and in different seasons can be used to develop a school-level biodiversity mapping project. We request teachers to try this unit in their classroom and share their experience with us.

Key takeaways

- This learning unit provides an opportunity to identify students' preconceptions about the existence, source, and dormancy of microorganisms and discuss them in the classroom.
- It helps students connect concepts related to microorganisms from the science curriculum with the diverse microorganisms found in their own surroundings.
- It also offers students the opportunity to develop scientific skills like observing, hypothesising, drawing, and measuring.

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Notes:

1. The activities in this article were developed as part of the CUBE (Collaboratively Understanding Biology Education) lab. CUBE is a program engaging students in project-based science experiments. More information about the CUBE program can be viewed at: https://www.gnowledge.org/projects/cube.html and https://metastudio.org.
2. The learning unit based on the activities were developed as part of the Vigyan Pratibha project. The objective of the project is to develop scientific skills with learning units related to school curricula. Currently the learning units are implemented by teachers in Kendriya Vidyalayas, Jawahar Navodaya Vidyalaya, Atomic Energy Central Schools. The entire learning unit with students' worksheet, and guidance for teacher's is available at: https://vigyanpratibha.in/index.php/microorganisms-at-our-doorstep/. Various other learning units for grades VIII & IX, and more information about the project can be viewed from: https://vigyanpratibha.in/.
3. Source of the image used in the background of the article title: https://pixabay.com/photos/trees-mirroring-puddle-rainwater-1932148/. Credits: Peggy_Marco, Pixabay. License: CC0.

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