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# Design of symbolic science characters: A visual design exercise with children

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**Abstract**: Over the years, in the context of education, domain experts have emphasized the importance of visual thinking. It is hence becoming vital for design-education researchers to investigate ways through which we can encourage and strengthen the visualization skills of learners at school level. We conducted an exploratory study with 90 secondary school students, which involved providing them specially designed textual cue cards explaining eight science concepts. Students were told to list keywords from the text and draw characters based on the cue cards. Our analysis revealed that listing keywords as a strategy did not necessarily help students to design the characters. We found that our implicit and explicit cues in the cue card aided in character design as students' drawings represented many physical and theoretical cues; but there was no clear preference of one over the other. In addition, we discuss some examples of students' characters reflecting anthropomorphism as a characterization strategy. Lastly, we present certain examples of text to image depictions of some specific words.

***Key words: children's drawings, visual representation, characterization***

## 1. Introduction and Background of the Study

How hot do you think is the red giant star? Did you know that something as small as a lymph node can help you fight off infections? Do you know what powers the cell? These are the kind of questions one may witness in a classroom by a teacher to initiate a discussion while introducing a new topic. When children in a science classroom are posed with such questions, it opens up a world of wonder and curiosity. The world of science offers students with many interesting facts and at times knowledge of complex phenomena such as the workings of the universe, our body system or new scientific theories and methods. When instructors present such new information to students in a classroom setting, often consisting of new vocabulary, facts and relationships, students while listening may create certain mental models or visualize concepts of what is being taught. But, one may wonder what happens to these mental images that students might have created in their minds while being introduced to a scientific text. According to Rudolf Arnheim (1980) who emphasized the importance of visual thinking for children, there exists a strong association between both verbal and visual literacy.

The ability to visualize text has been considered as a crucial aspect of literacy development and has shown positive impacts on students' learning (Newland, 2013; Woolley, 2010). In the context of science visualization, Gordin and colleagues (1996) have suggested that such visualization for students can be an interpretative and expressive medium. There have been studies arguing the use of pedagogical methods that include drawings along with words to link structure and function concepts (Mathai & Ramadas, 2006; 2009).

Learner-generated drawings refer to the visual representations that learners create by themselves while being involved in certain drawing activities to achieve a learning goal. Past studies (Leopold & Leutner, 2012; Mason, Lowe & Tornatora, 2013; van Meter, 2001) have shown that learner-generated drawings aid in reading comprehension and are found to be useful in educational contexts as they aid organizing, integrating, representing, and reasoning skills beyond surface-level understanding (Ainsworth, Prain & Tytler, 2011). Therefore, as design-education researchers we feel it is essential to investigate methods through which we can encourage and strengthen the visual representation skills of learners. The goal of this study is to use learner-generated drawing strategy (Schwamborn et al, 2010, van Meter & Garner, 2005) to investigate the text to visual transformation when children read a specific scientific text and design a character based on that text. We were partly inspired by the character design project by Dunlop Kaycie ("Elements - Experiments in Character Design", 2011) to take up this exercise with children.

## 2. Objectives of the Study

Drawing in typical educational setups is often limited to replicating scientific diagrams, biological illustrations, charts and graphs, geographical maps, or freehand to aesthetically pleasing drawings in an art class. Rarely is drawing used as a medium of understanding, information processing or communication in schools.

In the Indian context, although drawings by children have been studied in the past to understand their ideas of science and scientists (Chunawala & Ladage, 1998), explore their design drawings (Khunyakari, Mehrotra, Natarajan & Chunawala, 2004) and the visual and spatial modes in science learning (Ramadas, 2009), children creating characters from scientific texts has not often been a research focus. Further, learner-generated drawings that have been studied in the context of science; for instance, have focused on undergraduate students for generating textbook like drawings (Youngsun, 2017). However, we were interested in using learner-generated drawings with secondary school students to draw representations, which were more exploratory. Therefore, for this study we provided secondary school students cue cards explaining a few science concepts. Students were asked to design and draw visual characters based on the cue cards. Following were our research questions:

i. Given the creative task to visualize scientific principles as characters, does listing of important keywords from the text aid as a useful design strategy?
ii. If the text is categorized as cues consisting of physical and theoretical attributes, then which cues are prominently seen in student drawings?
iii. Are there any specific text to image depictions or visual patterns in the way students represent certain traits such as power, expansion, etc.?

## 3. Sample, Procedure and Material Details

### 3.1 Participants

At the National Science Day (NSD) 2019 organized by HBCSE, the Design and Technology lab conducted an open design workshop for children. 90 students in the age group of 14-17 (belonging to grade 9, 10 and 11) from various schools in Mumbai participated in this activity. They came in batches of 15-20 and stayed for no more than 20 minutes. The group size was 3 or 4 and all groups were single-sex (based on students own choice) and comprised of a total of 56 girls and 24 boys.

### 3.2 Procedure

During NSD 2019, students at the D and T workshop were involved in designing a symbolic character based on the written description of a science term. For this exercise, we had prepared 8 science cue cards (for example- Red Giant, Lymph nodes, Covalent Bond, Chloroplasts) on which the title and description of the science term was printed. Groups of students randomly picked one of these cards and were then asked to create a character in 20 minutes. Along with the cue cards, students were given a worksheet to fill in personal details and list important keywords and draw their characters. They were given a basic set of instructions, which included duration of the exercise, working as a team, filling in the worksheet and most importantly making a list of important keywords from the text. Along with the worksheet, students were also provided pencils and a set of colors. Students were encouraged to be creative and not stick to textbook like drawings for their characters. The procedure of identifying keywords for important information was left to the participants.

### 3.3 Science cue cards: Criteria, format and descriptions

Individually printed cue cards were used as the only source of information provided by us to introduce and explain a science term to students in this character design exercise. These cards were prepared using a specific criteria with carefully chosen words and presented in an easy-to-read format to students. Following were the criteria used for the science cue cards:

- The description was a combination of nouns (like powerhouse, strength), verbs (sharing, fighting, expanding) and adjectives (velvety, pear-shaped, powerful, attractive, red) that had potential to spark creative visual representations.
- The selected terms were within the scope of the syllabus, but not necessarily mapping one on one to a concept. Thus, the terms were a mix of both familiar and unfamiliar concepts. For example, we included “Chloroplast” and “Mitochondria” which are familiar terms across central board (NCERT) and state board (SCERT) and which were prevalent across textbooks and grades. On the other hand, “Red Giant” though featured in SCERT textbooks, would be more unfamiliar to students, as compared to the former terms.
- Terms spanned over three disciplines: physics, chemistry and biology.

*Format of the cue cards:* All the cards were in English and were printed on a foldable card. The cards were designed for easy handling and readability. We had eight cue cards, each card had a title followed by a description (5-11 lines). All the cue cards also had one important keyword highlighted as a guide for both listing and characterization.

*Source of descriptions:* All the terms we used in this study are at the very least mentioned in NCERT and/or SCERT science textbooks. While most of the terms (Mitochondria, Chloroplast, Villi, Lymph node, Gallbladder, Covalent bond, Red Giant) are discussed to a certain extent in the textbooks, other terms (like Pulsar) chosen by us find a cursory mention. We could not find any clearly defined evolution of the way the term/ topic was discussed in the textbook. The textbook visuals that accompanied many of the biology terms were mostly 2D diagrams with occasional diagrams trying to show cross-section of an organelle/organ. The terms used for this study were reconstructed by including what we considered as potentially more ‘visual words’ such as big, small, bean shaped, velvety, strong, etc. that may aid in visual representation. Apart from the textbooks, we referred to multiple digital sources, primarily Wikipedia (https://www.wikipedia.org), in addition to other popular science and encyclopedia websites to construct the final description. Prior to this exercise with students, domain experts were consulted to check the accuracy of the definitions, and changes were made accordingly.

**4. Method of Analysis**

The main purpose of conducting this study was to investigate the nature of students' visual representations in the form of character design from a science term. Additionally, we were interested in investigating the advantage of listing important keywords from a given text prior to creating their drawings as a strategy for character design. We analyzed 29 drawings developed by 90 students (working in groups) who belonged to grade 9 to 11. These 29 drawings depict designed characters of the various science related terms mentioned above namely, Villi, Chloroplast, Mitochondria, Lymph node, Gallbladder (Biology), Pulsar and Red Giants (Physics) and Covalent bond (Chemistry). Following are the list of the terms and the number of groups who attempted the drawing on the term: Covalent bond (CV)-2; Gallbladder (GB)-2; Lymph node (l)-3; Villi (V)-4; Mitochondria (M)-5; Chloroplast (C)-6; Pulsar (P)-3; Red Giant (RG)-4. All the groups were then analyzed in terms of list of keywords written by students and the drawings generated by them.

Analysis of keywords list: The list of keywords for each drawing were examined with reference to the explicit and implicit cues we had purposefully included in the cue card. By 'explicit' we refer to the prompt that was highlighted by us in the cue card, while 'implicit' refers to the list of words that we identified as potential cues but were not highlighted in the card. The total number of cues identified by us were 46. We checked for overlap of the keywords listed by groups with our potential cues, which included the highlighted prompt and implicit cues.

Analysis of drawings: The drawings were closely examined for depiction of the core concept, physical and theoretical details included in the representation and use of other representation techniques such as text (labels and descriptions) or use of metaphors. Drawings were assessed on layers of personification, physical appearance and use of colours and texture. Similarities and differences in visual representations were noted and observations were made on text to image relationships.

## 5. Findings and Results

The primary goal of this exploratory study was to inspect the advantage if any, of using the strategy of listing keywords as an aid to the character design process. We examined this objective by investigating whether students prepared a list of keywords prior to designing the character. If they did, were these keywords used as a strategy to design traits of their characters? Secondly, we examined whether the listed keywords included our explicit or implicit cues. In the following sections, we elaborate on these findings.

### 5.1. The relationship between listing of keywords and character design

As part of the listing exercise, the participants were informed that one of the important traits was highlighted in the cue cards. They were told to find more of such keywords and that these keywords could then be used to aid their character design. We found that of the 29 groups who submitted drawings, 25 (86%) listed one or more keywords. Among these 25 groups, 5 groups (20%) listed only the explicit cue (provided by us), 17 groups (68%) listed keywords which included our explicit cue along with others, and another 3 groups (12%) listed keywords other than our explicit cue (Refer the section on 'Analysis of keywords list'). We then examined how many groups attempted to translate their (listed) keywords to drawings. All but one group (24 out of 25), that is 96% reflected one or more keywords listed by them, in their drawings.

When we examined how many of the total number of listed keywords were translated into characters, we found that 69% (38 keywords out of 55) were represented in students' drawings. On the contrary, when we analyze drawings for presence of our intended (implicit) keywords that are not listed by the groups, we find that 24 drawings (82%) represented the implicit cues without a mention of it in their lists. Thus, whether they prepared a list of important keywords or not, the cues were translated into drawings from the written cue cards. Therefore, we speculate that listing as a strategy has not necessarily helped students to create the characters. This is because the percentage of groups translating listed keywords to visuals (69%) is similar to those who represented our cues in their drawings without listing them (82%). Further, CV1, GB1, P1 and C1 wrote no keywords, yet all the drawings except P1 showed the presence of our explicit cue.

Listing keywords of important concepts has been cited as an important aid for learners to create more explicit drawings, representing conceptually accurate information (Youngsun, 2017, p. 16). Although, this might seem true for generating scientific drawings, in our study of designing symbolic characters, listing keywords did not necessarily help in character design. This could be due to lack of information on the benefit or procedure to use keywords in the process of character design.

### 5.2. Physical and theoretical attributes in character design

Form and function are an important aspect of the design process. For character design as well, form and function are crucial to understand and depict the appearance and personality of the designed character. As we mentioned earlier, the descriptions given to students as printed cue cards were intentionally made to include numerous cues (46) which may aid in characterization and not necessarily only for concept learning. The 46 potential cues that we identified were further subdivided into what we call 'Physical' and 'Theoretical' attributes. These cues were not exclusively disclosed (except the explicit cue) to the participants but were present in each cue card for the students to figure out. Physical (or structural) attributes were the ones that were tangible in nature (in form /colour /texture /appearance), while the theoretical (conceptual) ones were, those that were more concept oriented and could be abstract in nature.

Here is an example: Lymph nodes are small bean (or kidney shaped) shaped organs. They play a vital role in your body's ability to **fight off infections**. They function as filters, capturing viruses, bacteria and other causes of illnesses before they can infect other parts of your body.

| Physical Attributes | Theoretical Attributes |
|---|---|
| Small<br>Bean/kidney shaped<br>Fighting<br>Capture<br>Virus, bacteria | Fights off infections (explicit cue)<br>Functions as filters, capturing virus, bacteria |

Table 1. List of physical and theoretical cues in the Lymph Node cue card

Thus, as shown in the table 1, we categorized the original 46 cues into a total of 68 cues (in 8 cue cards), of which 46 were selected as physical attributes and 22 as theoretical attributes. Some words may fall under both categories and have been counted under both. We then independently checked for the presence of each physical and theoretical cue in the concerned drawings and tabulated the data. Any conflicts were resolved through discussion and consensus amongst the researchers.

Overall, around 76% of our physical cues and 72% of the theoretical cues featured in students' drawings. Therefore, students did notice a majority of these cues and represented them in their drawings.

A 100% presence of a cue in the drawings would mean that all the concerned drawings within a category would show the presence of that cue. For example, 4 out of 4 drawings of "Red Giant" showcased the physical attribute "red". But only 2 of 4 depicted the "high temperature" (both under a physical and theoretical cue). Thus, we analyzed independently the total percentage presence of physical and theoretical cues in students' drawings. For a total possibility of 161 representations of physical cues, that is each cue is represented in all drawings of that particular category; students' drawings showed 95 representations (59%). Moreover, for a total possibility of 75 representations of theoretical cues, students' drawings showed 45 representations (60%). Therefore, we can infer that in their drawings, students represented as many theoretically cues as physical cues. Thus, we are of the opinion that the words, which were chosen as (implicit and explicit) cues for students, did aid in their visual representation, however, there was no preference of one over the other.

### 5.3. Characterization in students' drawings and text-image relationship

From the design task's point of view, creating a science character was something novel for students unlike a textbook diagram or drawing. Overall, 86% (n=29) of the drawings showed characterizations. However, there were some similarities and differences amongst students' ideas of what they considered as "characterization". This section shares some examples that give insights into students' ideas about what is a character, its characterization and text and image relationships. For character design, two approaches emerged from children's drawings:

*Anthropomorphism*: It is the process of ascribing human attributes to non-human things. The new character may get a face consisting of eyes, nose, mouth and ears or have typical body parts such as two hands, two legs and hair.

*Representation of characteristic traits emerging from the text:* This approach leads to design of the character where form follows the text using the details provided in the text. The designed character may have human like traits such as eyes or hands but the shape, form, number or appearance will be a result of the specifications present in the text. To present an example of good character design in science education, we discuss the work of Dunlop Kaycie's project at the Milwaukee Institute of Art & Design in 2011. The project titled "Elements - Experiments in Character Design" represented the elements of the periodic table in an array of characters. The character's gender, physical appearance, emotions, colours, presentation, all represented a trait that was specific to a particular element. In her rich illustrations, she presented all the elements as superheroes possessing personified special characteristics and showed powers and problems of an element.

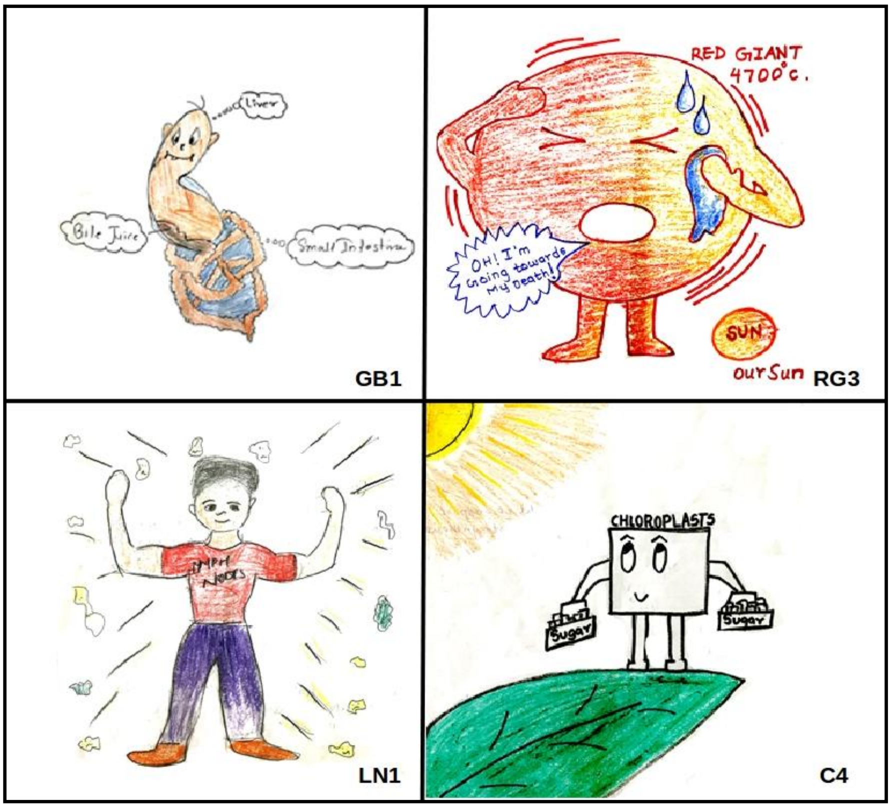


Figure.1 Students' drawing of Gallbladder (GB1), Red Giant (RG3), Lymph Node (LN1) and Chloroplast (C4) showing varying levels of characterization.

In our study, we observed that many groups took the approach of anthropomorphism to give their drawing a character like feeling. There was a range of such representations. Some were as simple as the case of GB1 which looked almost like a textbook diagram but the drawing had a pair of eyes, nose, mouth and ears. (Fig 1). Others like C4 were more detailed drawings, but still incorporated the typical anthropomorphic traits mentioned above. Then, there were drawings like RG3 and LN1 that reflected a higher degree of sophistication in characterization, which overlapped with the second approach discussed above. Hence, as a learning from this study, in our future attempts, we need to caution participants from avoiding mere addition of human features onto a character. Instead, they need to look closely at specific characteristics, especially physical ones, in the text and design accordingly.

### 5.4. Text-Image relationship

It was interesting to see how certain similar words, which had different meanings in their context, were used in students' drawings. For example, depiction of the word "power" featured in the cue card of Mitochondria (powerhouse of the cell) and in Covalent Bond (powerful bond). "Powerful" as a trait was shown in terms of sharing a body part and use of a lit bulb (CV1) and strong jagged red lines at the hand joint (CV2). In M2 and M4, a yellow-lit bulb depicted power. Interestingly lit bulbs also featured in C2 to indicate light energy being absorbed by chloroplast cell (Fig 2).

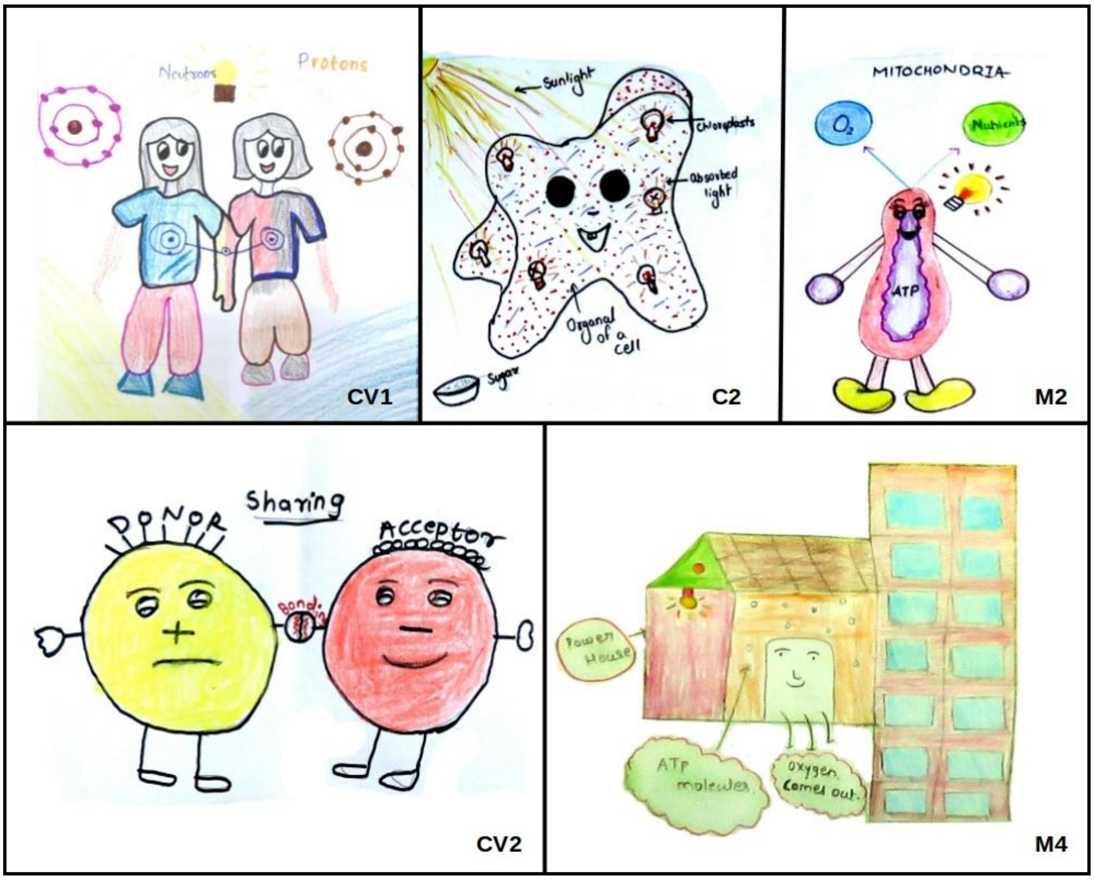


Figure.2 Students' drawings showing "power" and "bulbs".

Similarly, the word "expand" mentioned in the Red Giant cue card was depicted in different ways by students. For example, RG1 emphasized the outer layer with outward yellow rays, RG2 and RG4 showed the relative sizes by depicting smaller sized stars (previous stages of the red giant) next to the Red giant, while RG3 drew curved lines around the star to depict "expansion".

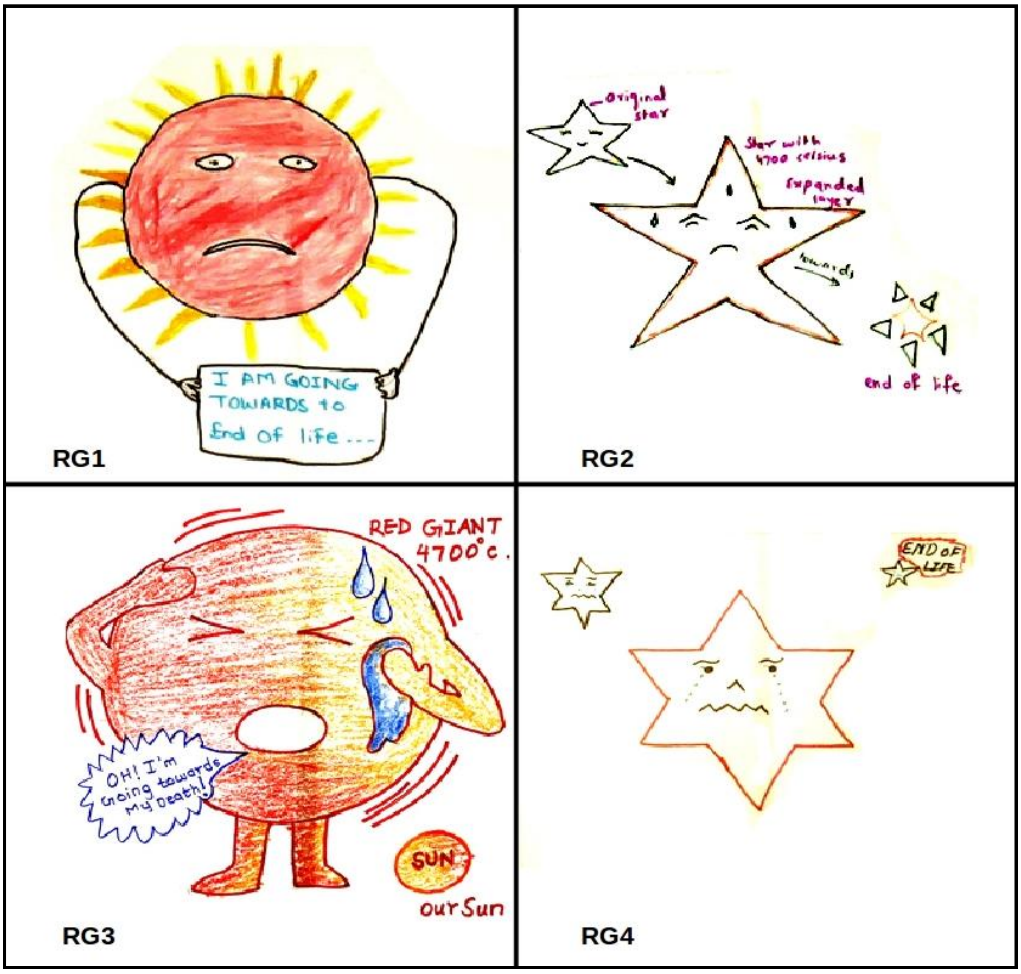


Figure.3 Depiction of expansion in student drawings

### 5.5. Students' misconceptions

Though studying students' conceptual understanding through drawings (Köse, 2008) was not the primary focus of this study, to gain a more holistic picture, we consulted three teacher-researchers cum domain experts to provide their insights into students' science conceptions using this exercise. According to the astronomy expert, one of the drawings on pulsars revealed students' misconceptions of relative positions of the sun, earth and stars. To be fair to the group of students, it was also acknowledged that pulsars are a relatively unfamiliar and complex concept to understand and it has multiple layers of information and is hard to visualize, especially for students with less exposure to activities on visual thinking. In one of the drawings of covalent bonds, there seemed to be a misconception as there was presence of "charged" particle, which is in the case of ionic bonds, and not covalent bonds. Similarly, the biology expert pointed out that in one of the gallbladder drawings, there was a depiction of inaccurate relative sizes of organs. Thus, a preliminary analysis of students' drawings revealed student misconceptions that teachers can address in class. Therefore, we think this exercise of drawing science characters has potential to be used as a diagnostic tool by teachers in the classroom to evaluate the conceptual understanding of students and identify misconceptions.

## 6. Discussion

Firstly, our findings indicated the presence of at least one or more cues (explicit or implicit) in almost all of the students' drawings. These cues were not always written in the form of a list of keywords but were depicted in their drawings. Thus, it indicates that the act of writing a list of keywords did not necessarily contribute to creating characters. We speculate that the presence of unlisted cues in the drawings would have been possible only because students read and re-read the text in search of important features. Moreover, we also found that though a significant number of cues were represented in the drawings, students did not have a preference of physical cues over theoretical cues or vice versa. More in-depth analysis is required to understand the reasons for this.

Secondly, both familiar as well as unfamiliar terms led to character designs from students. For example, covalent bond, mitochondria and chloroplast, which are amply discussed in the textbooks and were familiar terms and their characterizations by the students, were rich and diverse. However, red giant and pulsar, which were unfamiliar terms for students, also yielded rich characterization. This indicates that drawing science characters can be a fun exercise to do in science classrooms to either introduce a topic, familiarize with new vocabulary, spark creative expression, improve comprehension etc., since unfamiliarity was not a barrier to characterization. We also need to focus more on the instructions given to students prior to such a learner-generated drawing task and to identify ways in which listing keywords may aid in the character design process.

Lastly, to acknowledge a few limitations of this study, we did not perform a pre or posttest to measure learning or understanding in students and thus our comments on conceptual understanding is limited. The sample size for this study was low and hence we cannot make gross generalizations. Furthermore, drawing skills of students who may not be proficient in drawing may inhibit their participation in such exercises. Lastly, the domain experts we consulted expressed that such exercises may lead to misconceptions in students about scientific concepts, elicit empathy or restriction towards the system, which is untrue in reality. We hope to further perform such visual exercises in a more structured manner and study the consequences of the same.

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