GUIDEBOOK FOR UNPLUGGED COMPUTATIONAL THINKING

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SEAMOLEC
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Guidebook for Unplugged Computational Thinking

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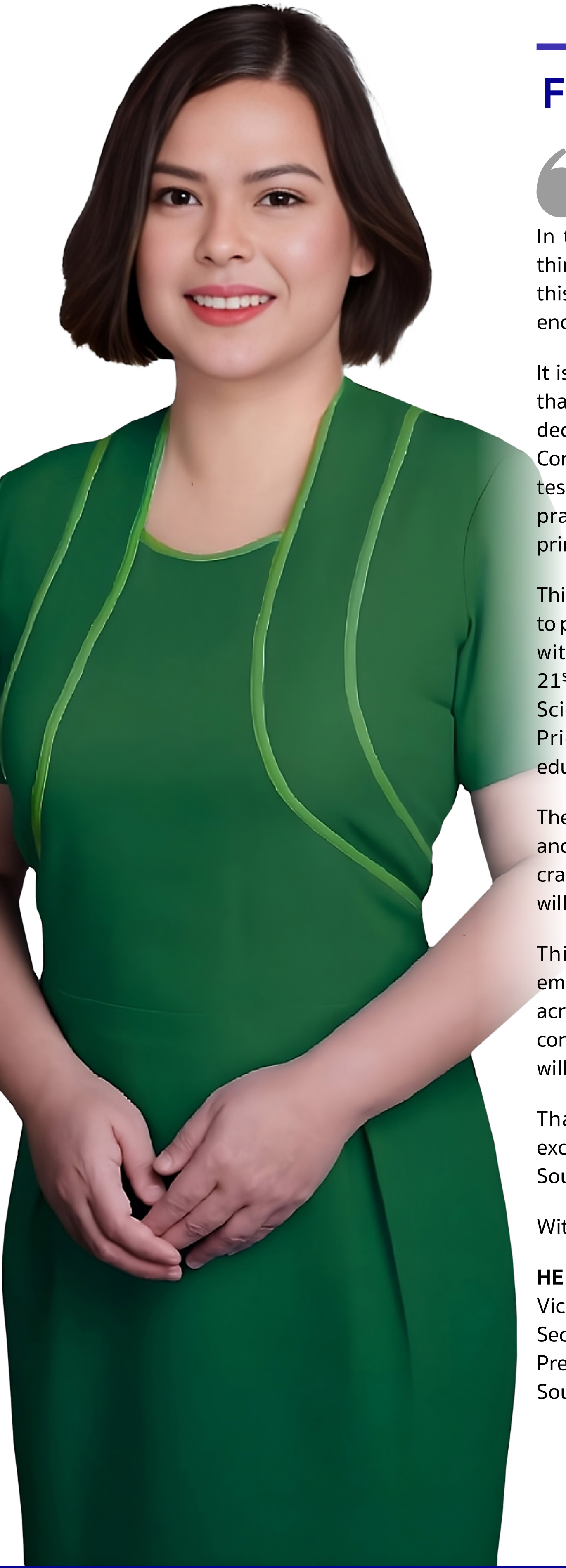

Foreword for SEAMEO STEM-ED's Guide Book

In the dynamic landscape of education, fostering computational thinking is a beacon of progress and innovation. The journey to embed this essential skill in our primary education systems is not a solitary endeavor but a collective pilgrimage.

It is with profound pleasure and gratitude that I extend my sincerest thanks to the editors and contributors of SEAMEO for their unwavering dedication and expertise in crafting the 'Guidebook for Unplugged Computational Thinking' for Primary Education. This publication is a testament to our collective commitment to advancing educational practices through innovative and practical activities tailored for primary school teachers.

This guidebook marks a significant milestone in our ongoing efforts to promote computational thinking among young learners. It is aligned with SEAMEO's Education Priority Area No. 7, which emphasizes 21st-century skills, and Science Priority Area No. 6, focusing on Data Science, Analytics, and AI. Furthermore, it resonates with Science Priority Area No. 7, which underscores the importance of STEM education for future readiness.

The exercises within this guidebook, ranging from 'coloring activities' and 'Math & STEM activities' to 'visual programming,' are meticulously crafted to engage students and cultivate critical thinking skills that will benefit them throughout their academic and professional journeys.

This publication stands as a testament to our shared vision of empowering educators and nurturing the minds of young learners across Southeast Asia and beyond. As we look toward the future, I am confident that the insights and activities presented in this guidebook will continue to inspire and equip educators and students alike.

Thank you once again to the editors and contributors for your exceptional work. Together, we are shaping the future of education in Southeast Asia.

With warm regards,

HE Ms Sara Zimmerman Duterte
Vice President of the Philippines,
Secretary of the Department of Education
President of SEAMEO Council,
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Preface for Users

'Have you ever wondered how to teach computational thinking without using computers?'
'What basic informatics content is suitable for primary school students?'
'How can we fit these lessons into our already packed schedules?'

This booklet is designed for primary school teachers who grapple with these questions, offering classroom activities that can be conducted both with and without computers. Under the title **'Unplugged Computational Thinking'**, the editors assert two aims. First aim is that children are able to experience computational thinking without using computers. Second aim is that children are able to experience computational thinking with using computers.

For the first aim, we have developed three types of activities. First, 'colouring activities' encourage development of computational thinking through natural language, which is foundational for using generative AI and reasoning for programming. Second, 'mathematics activities' promote mathematical thinking through various representations, essential for informatics and beyond. Third, 'STEM activities' foster STEM thinking by engaging children in designing, creating, and valuing products using computational, mathematical, and scientific inquiry skills.

On the second aim, we offer two types of activities. The first involves 'visible programming activities' using Scratch programming. The second includes 'Designing Robot activities' using Blocks and Scratch programming, which also serve as STEM activities.

Each activity is designed for children to promote computational, mathematical, and STEM thinkings, with task sequences from challenging tasks to open exploration tasks. Open exploration tasks provide a moment for children to reflect on the experience and appreciate the value of what they have learned from the challenging tasks.

Additionally, the booklet provides appendixes that clarify computational, mathematical, and STEM thinkings, along with references for further learning.

This booklet represents the first phase of our project. In the next phase, we hope to collaborate with you to further develop and implement these educational ideas. We look forward to embarking on this educational journey with you.

Editors

About Unplugged Computational Thinking Project

The roots of Coloring Book which aimed to develop computational thinking originated in the 2002 FONTEC project # 202-3238 of AutoMind Chile, financed in part by CORFO of the Government of Chile (Araya, R., 2004). APEC Lesson Study Project proposed by CRICED, University of Tsukuba, Japan and IRDTP for ASEAN, Khon Kaen University, Thailand has been promoted in Mathematical Thinking. Under the necessity of Digital Society, APEC Project named InMside was proposed by Japan, Thailand, Chile, and Malaysia on these experiences and published 'Developing Computational Thinking on AI and Big Data Era for Digital Society (Isoda, M, Araya, R, & Inprasitha, M., 2021)'. For promotion of the Reform movement, CRICED began the ArTeC Robo project for Robot Programming with the leading institutions SEAMEO STEM-ED, SEAMEO QITEP in Mathematics, SEAMEO RECSAM, and IRDTP for ASEAN (2019).

After COVID-19, the emergence of Generative AI, which uses natural language, strengthened the necessity of Unplugged Computational Thinking. The collaborating institutions joined SEAMEO STEM-ED and CRICED with support of Araya's resources. SEAMEO STEM-ED handles SEAMEO projects and collaborating institutions lead their country. CRICED handles APEC projects with IRDTP for ASEAN.

This booklet published from SEAMEO STEM-ED is the preliminary achievement to accelerate the reform in Southeast Asia based on the experience of collaborating institutions. It is prepared for lesson study at primary level to develop Computational Thinking.

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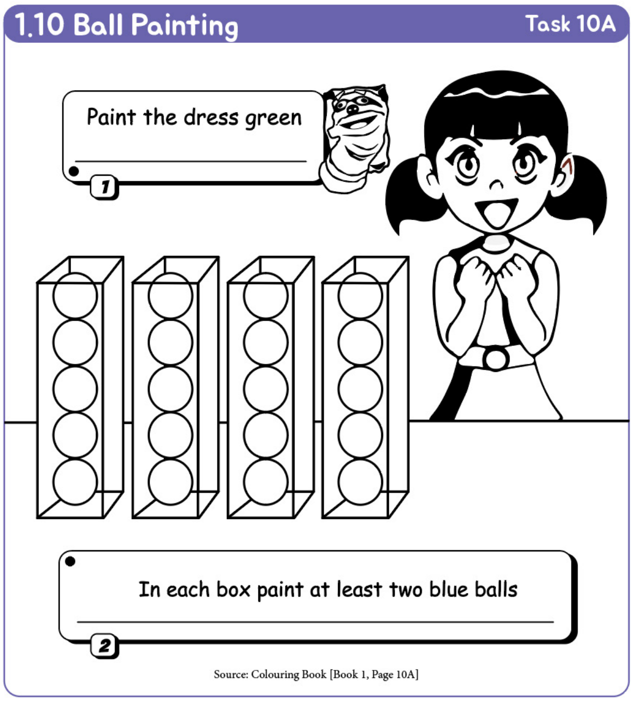
Contents

How To Use This Booklet

Core Task



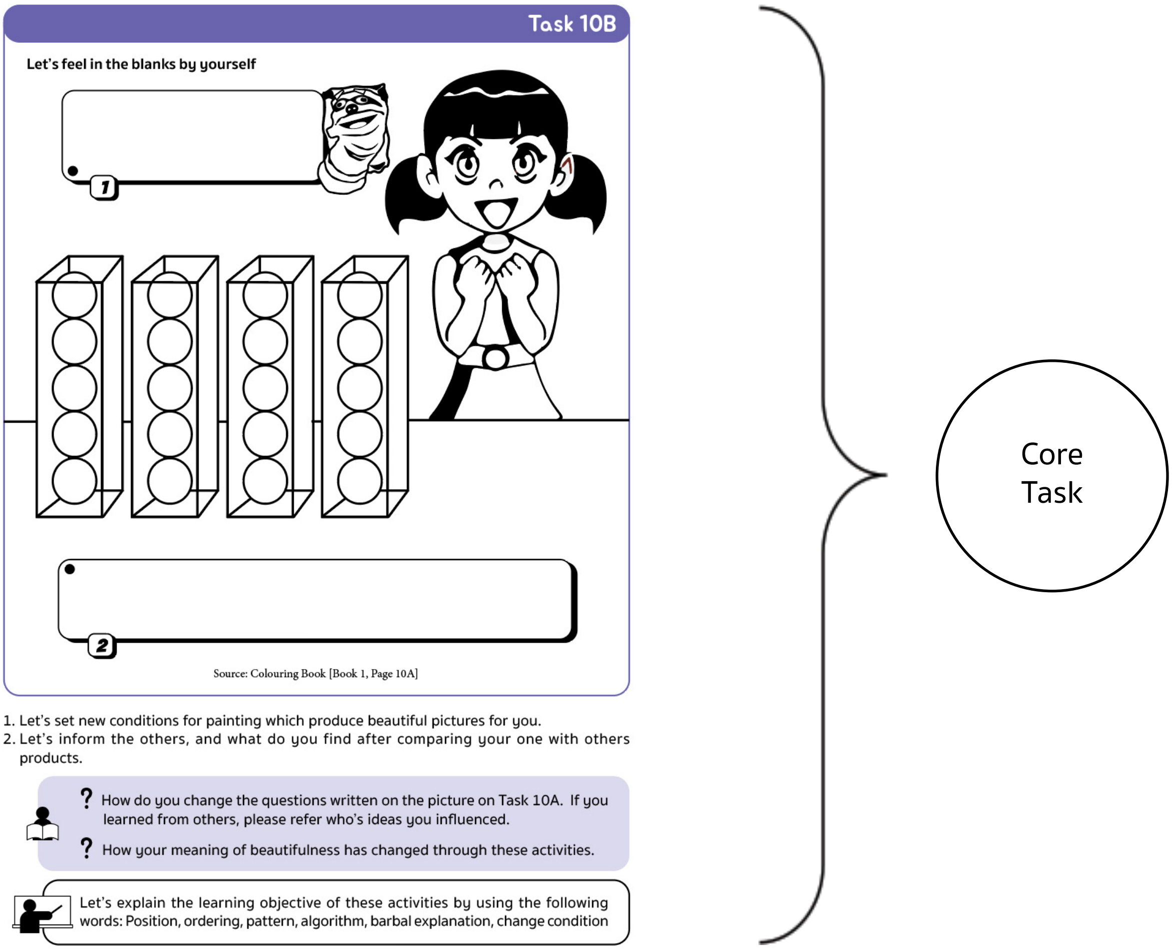
1. Let's design a beautiful picture on your unique painting based on the given condition. Then, present it to each other with an explanation.
2. Let's explain your unique manner without showing the original picture itself to your friends and the friends re-present the picture based on your explanation. And compare your friend's picture with your original picture.

? Through the comparison with others, let's think whose explanation is most understandable for you and appreciate whose one is really beautiful or unique for you?

? How do you use the condition of 'at least' in your painting?

Explanation of Format:

- Each activity set under the title is given by the task sequence.
  - In the case of 1.10 Ball Painting, Task sequence is given by only two tasks: Task 10A and 10B.
  - Each task provides the activity for each child to learn how to form the process.
  - Final task is the open task which provides the opportunity to reflect on the whole previous activities in the previous task and task sequence, and utilise their recently learned knowledge.
- The Core Task Part in each task is expected to be printed as a worksheet for each child.
- 'Student box parts' are suggestions for children. Teachers are expected to use them to support children's activities to promote each child, group, and whole class work.
- 'Black box parts' provide the suggestions for teachers on what we would like to teach. For making clear on the objective of each task and the goal of the task sequence, teachers shall finish the whole task sequence at first by finding the role and objective of each task through imagining how children emergent their ideas and ways of thinking by and for themselves. Final task is the opportunity for children to reflect on and utilise what children learned how to. Final task might be conducted by children for themselves as long as each objective of the task was well achieved by children.



Learning Process to Enhance 'Aha!' experience:

- First, each child engages independently and then, explains what s/he did to the others on each task for themselves in a group or whole class for re-presenting her/his 'Aha'.
- Children enjoy listening to others' explanations, and find the ways of explanations through comparison, and re-present 'Aha.'
- Teachers support children, positively through the prizing 'Aha': For example, the opportunity of comparison provides the opportunity of higher order thinking such as Meta Cognitions, Critical Thinking and so on. Only at the beginning, teachers are necessary to promote the discussion which they would like to focus on, possible to provide critical questions, and to summarise under the objective which children are able to do it by and for themselves in their next tasks.

For making clear the objective of each task and goal of task sequence:

- Teachers are recommended to read Appendix of this booklet to understand Computational Thinking, Mathematical Thinking and STEM thinking,
- Because these are ways of thinking, teachers are expected to write their objective/goal by the sentence like 'through (something process), learn/appreciate (any value, ways of thinking and so on): Do not recommend writing it as just several acquisition points without explanation of processes. Because process knowledge and skills such as ways of thinking and values, are only possible to learn through the reflection of the process.

CHAPTER 1

< back to contents

Using Coloring Books

1.1 Piano Playing

Task 1A

Piano red

1

Hair brown

2

Top cat gray

3

Dress pink

4

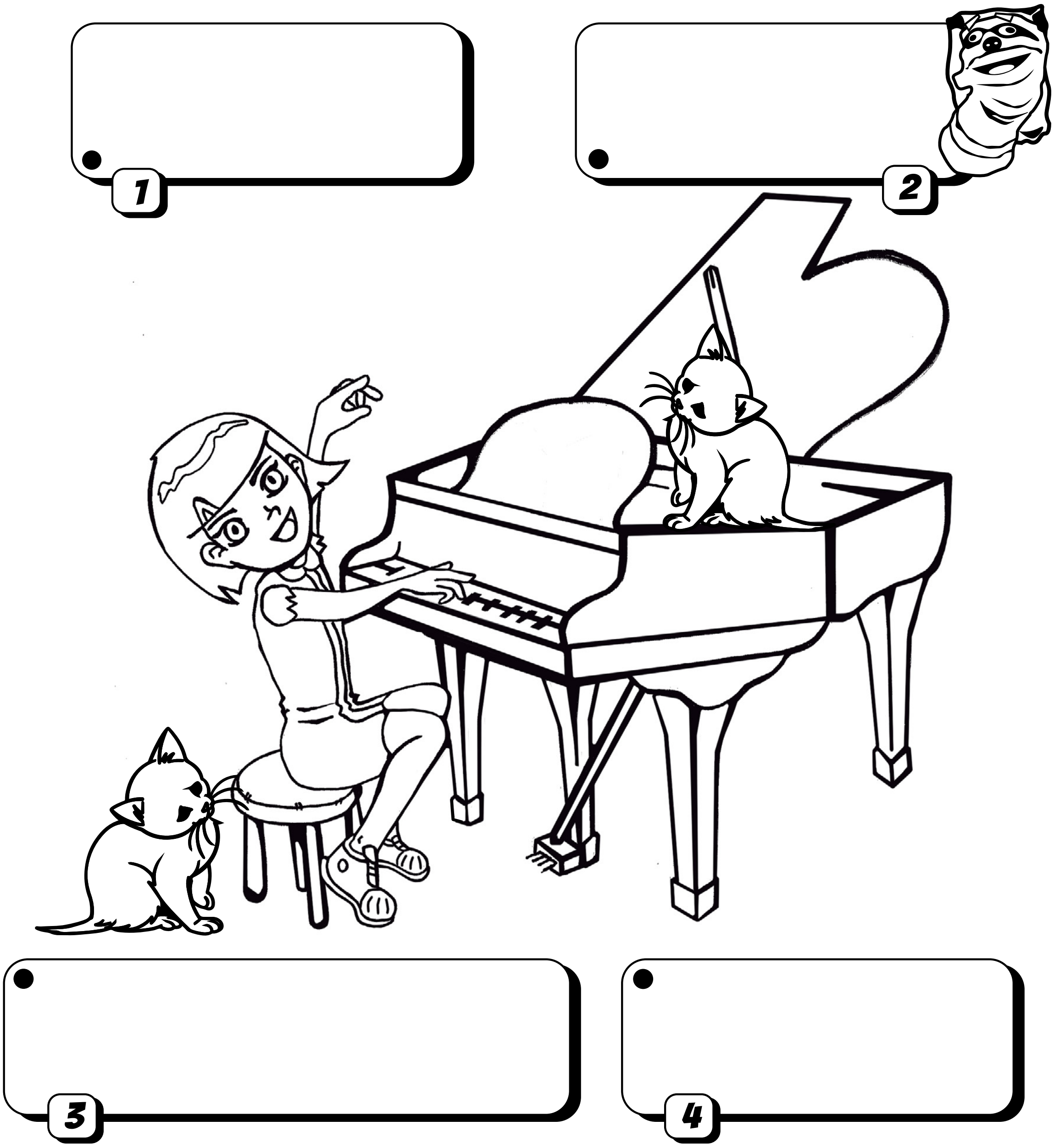
Source: Colouring Book [Book 1, Page 1A]

1. Let's show your painted picture to your friends. Is it the same as others?
2. Let's explain your order of painting commands to the others.

? Discuss how they follow each command and the order of them as well as the beauty of each picture: How they painted for the objects which do not mentioned in the boxes: It is free. Their used of painting tools such as crayons, coloured pencils and magics also function as keys for difference.

? On your friend's picture, re-present the order of its painting by yourself.

Task 1B



Source: Colouring Book [Book 1, Page 1B]

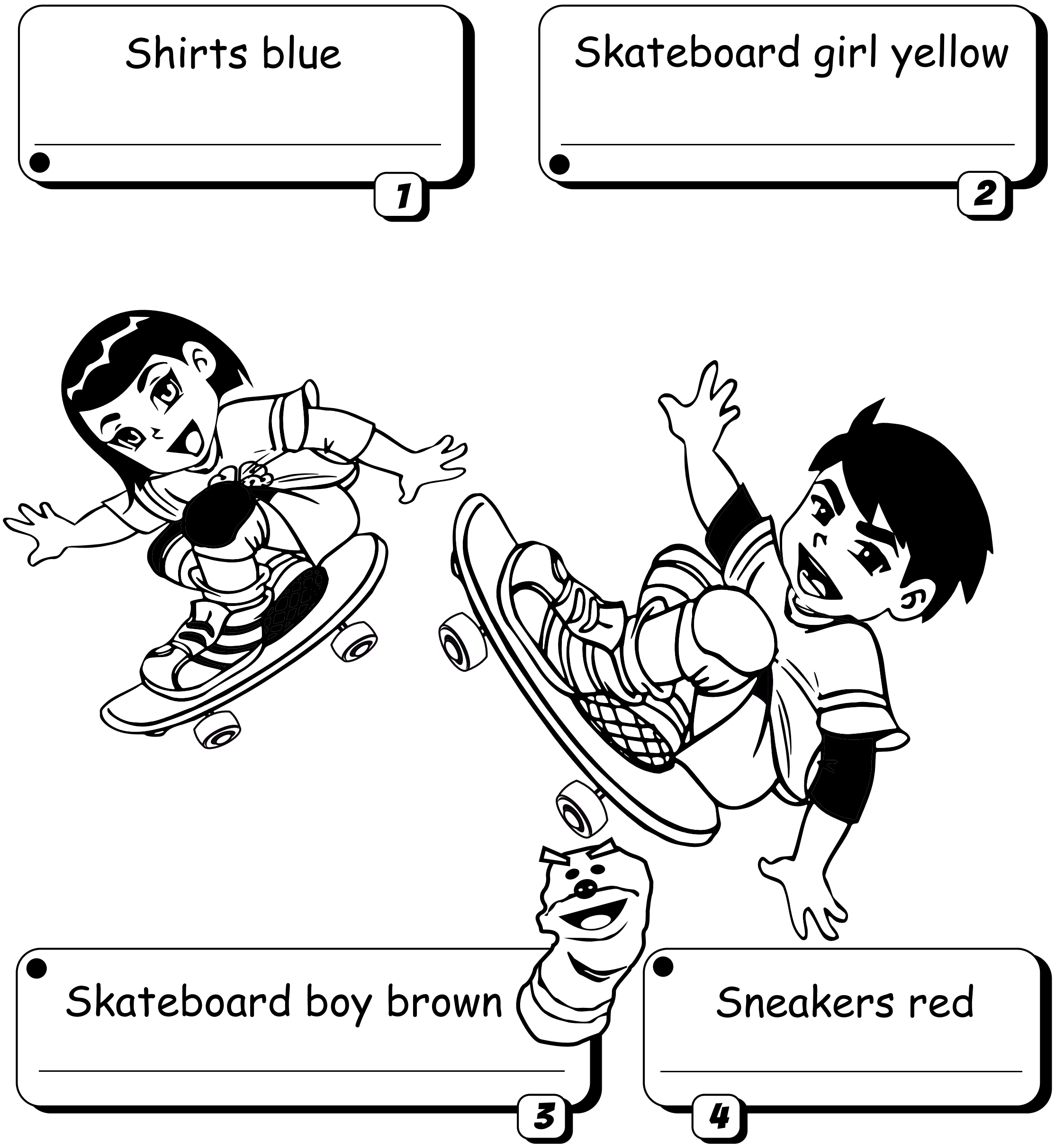
1. Let's fill in commands' boxes to design a beautiful painting by yourself.
2. Order of Commands or painted picture, which one you would like to present to the others and why?

? Discuss the beauty of each picture in relation to commands setting.

Let's explain the learning objective of these activities by using the following words: Beautifulness, Appreciation, Develop Explanation, Re-present other's idea, Conditions

1.2 Skateboarding

Task 2A



Source: Colouring Book [Book 1, Page 2A]

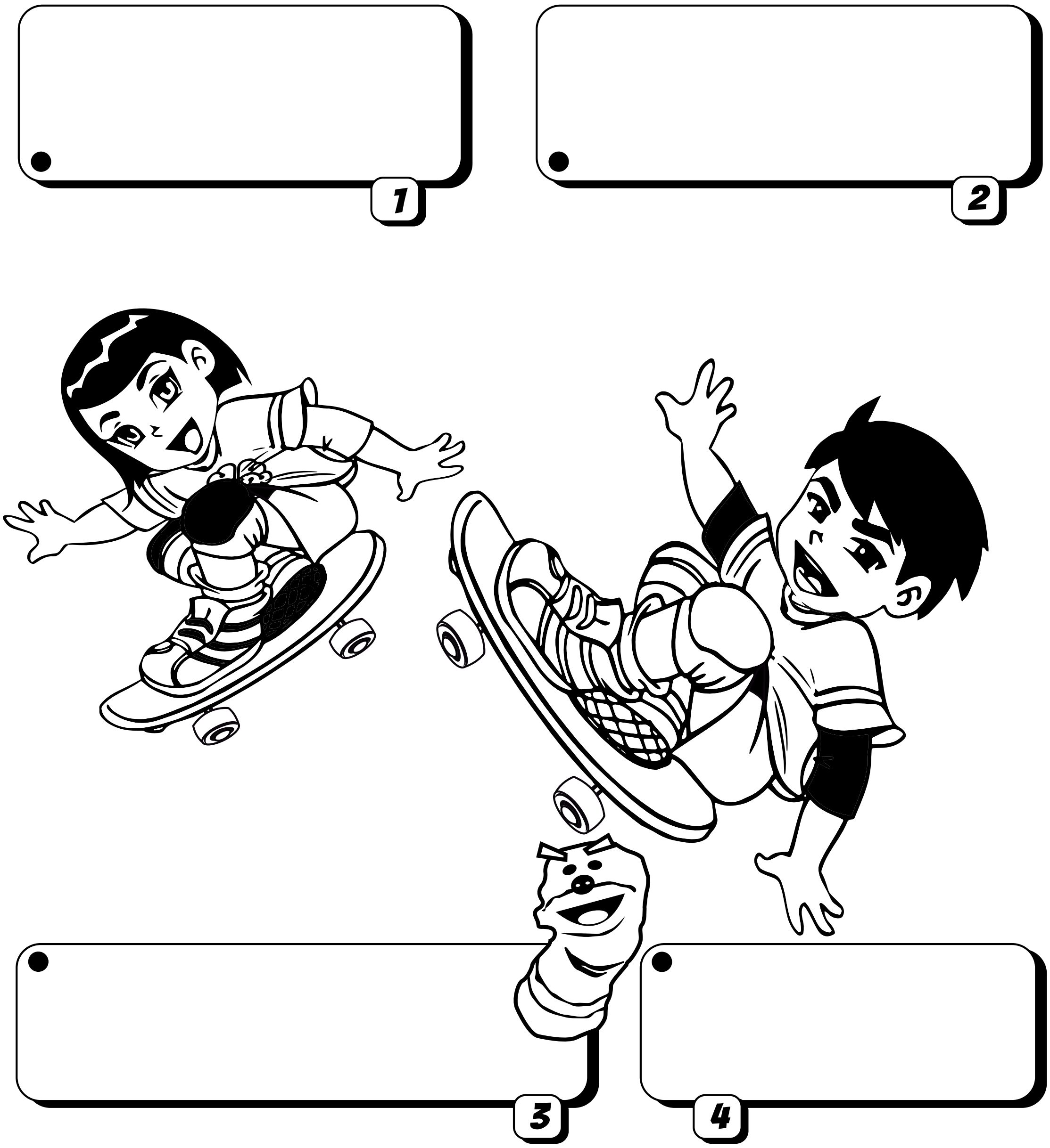
1. Girl and boy wear shirts and use sneakers: How do you follow commands?
2. Let's show your painted picture to friends. Is it the same as others?

? There are problems in making decisions for layer painting or not. How do you decide? Layer painting produces beautiful colours or not.

? Let's see your friend's pictures, can you re-present the ways of painting by your friends?

< back to contents

Task 2B



Source: Colouring Book [Book 1, Page 2B]

1. Let's fill in commands' boxes to design a beautiful painting by yourself.
2. Order of Commands or painted picture, which one you would like to present to the others and why?

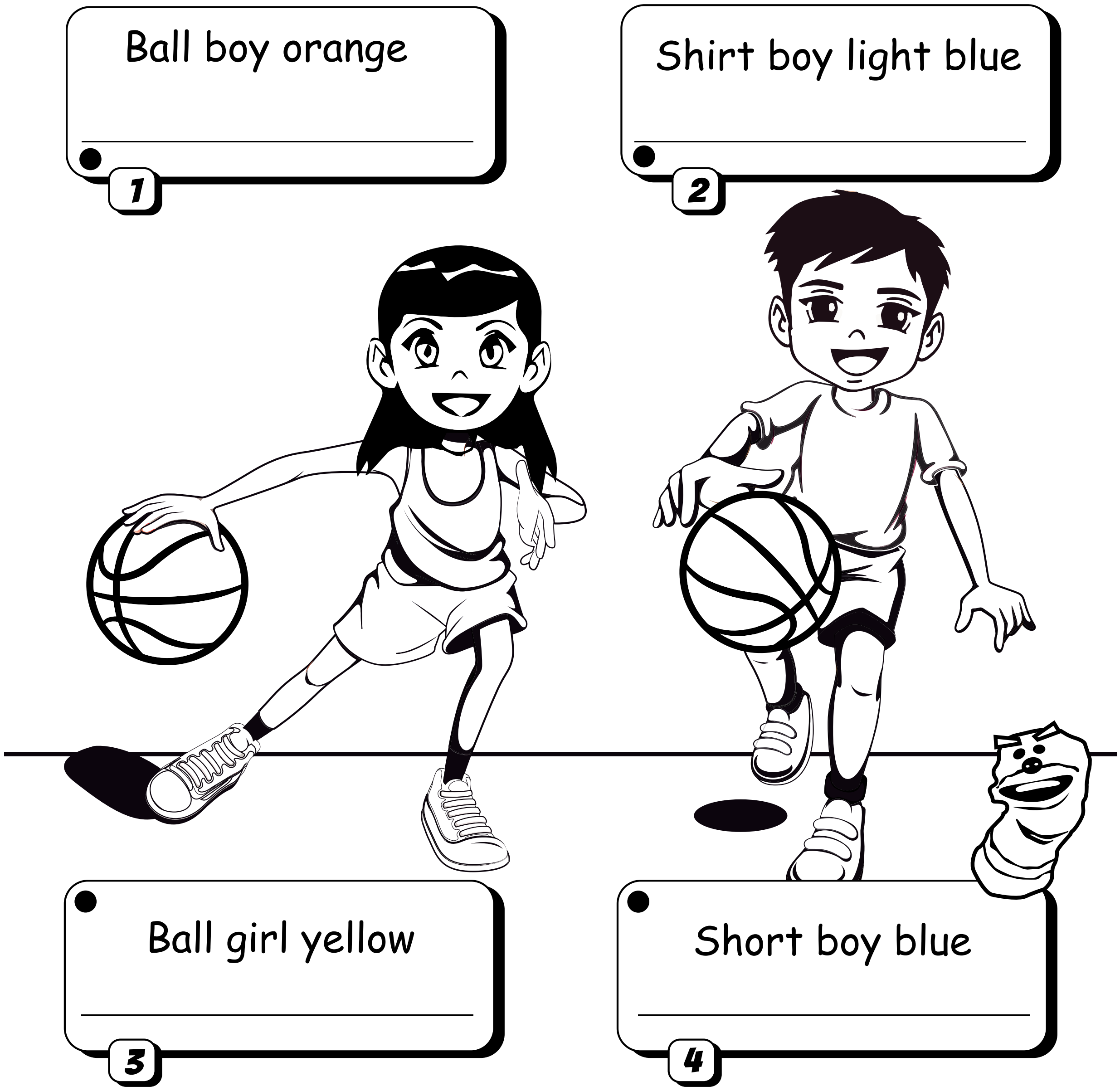
? How do you distinguish objects for painting? Do you consider the commands which produce the Layer painting?

? Can your friend's painting be explained by four ordered commands?

Let's explain the learning objective of these activities by using the following words: Set and condition, unique algorithm

1.3 Playing Basketball

Task 3A

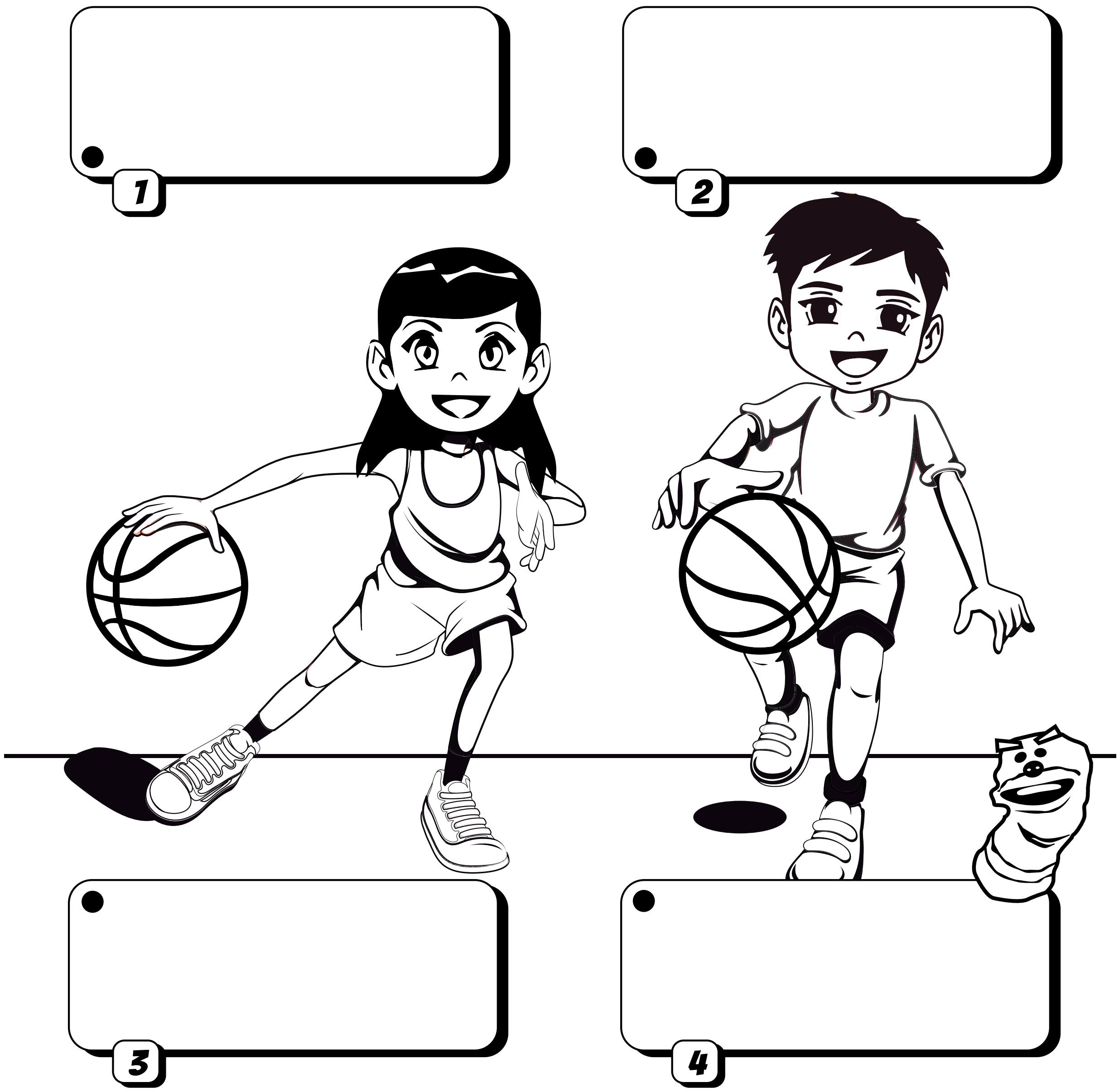


Source: Colouring Book [Book 1, Page 3A]

1. How do you interpret every command in each box?
2. Let's show your picture to friends and others explain your picture how you interpret it.

? There are possibilities of interpretations such as 'Ball for boy' or 'Ball-Boy' and 'Shirt for Boy' or 'Shirt-Boy', and 'Ball for Girl' or 'Ball-Girl' and 'Short for boy' or 'Short-boy.' Which interpretation is reasonable and which interpretation produces the contradictions.

Task 3B



Source: Colouring Book [Book 1, Page 3B]

Let's fill in the command boxes and enjoy the questions. What does it mean?

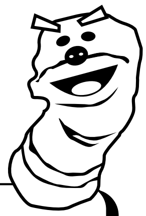
? Maximum only three words are possible to fill in each command box.

? Do your friend commands are meaningful for unique colouring?

Let's explain the learning objective of these activities by using the following words: Problem posing, Develop explanation, Set and conditions, ordering of the words

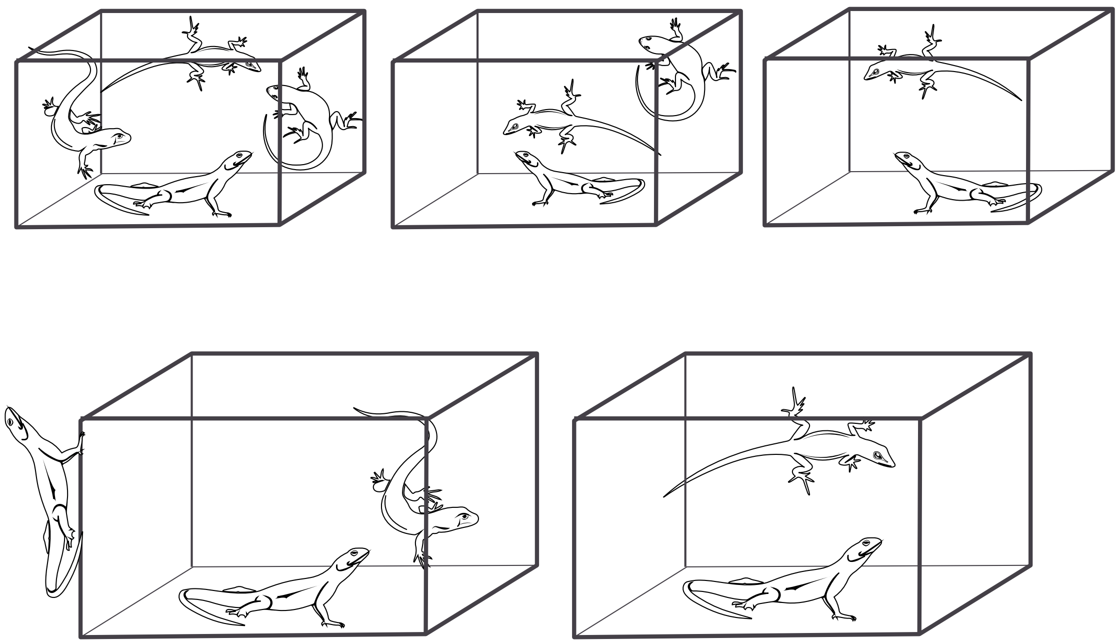
1.4 Lizards in the Boxes

Task 4A



Connect the box with a lizard outside

1



In each box paint at least one blue and one red lizard

2

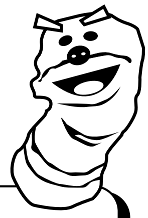
Source: Colouring Book [Book 1, Page 4A]

1. How do you explain if lizard is inside or outside?
2. How do you use the words ‘at least’ for painting?

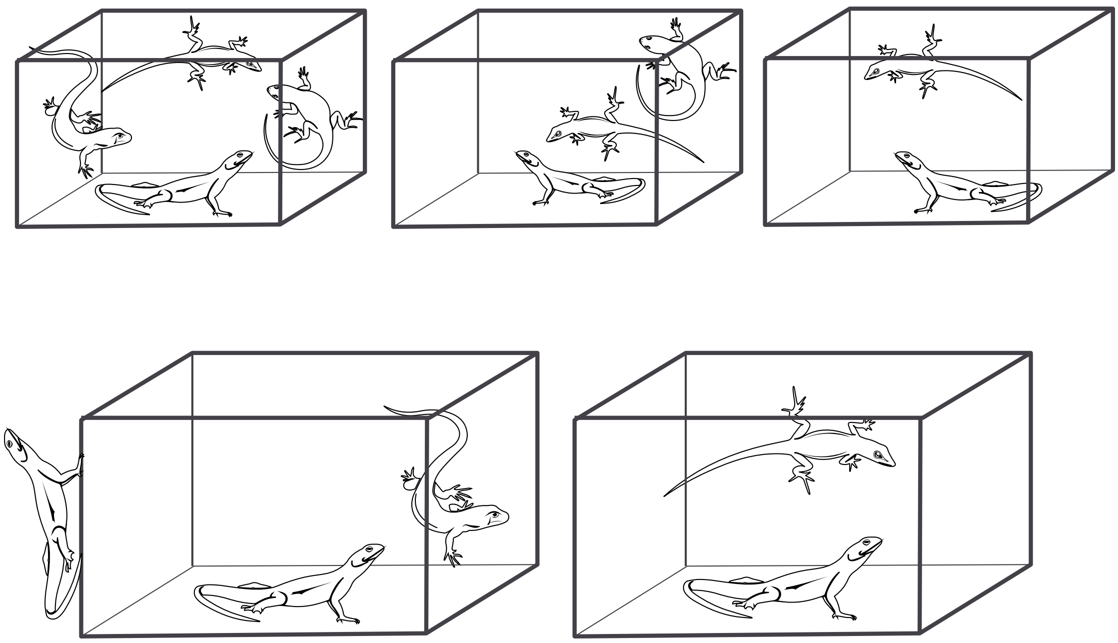
? For connection, we have to find any evidence which can say it is outside of the box.

? When we say ‘at least the number,’ that number is included or not?

Task 4B



1



2

Source: Colouring Book [Book 1, Page 4B]

By filling in the boxes, what questions would you like to pose and why?

? What is the antonym (opposite word) or synonym (similar word) of at least.

Let's explain the learning objective of these activities by using the following words: Number set and conditions, ordering, range and defining

1.5 Bike Riding

Task 5A

1 Paint helmets green

2 Paint the shorts of the boy and girl below blue

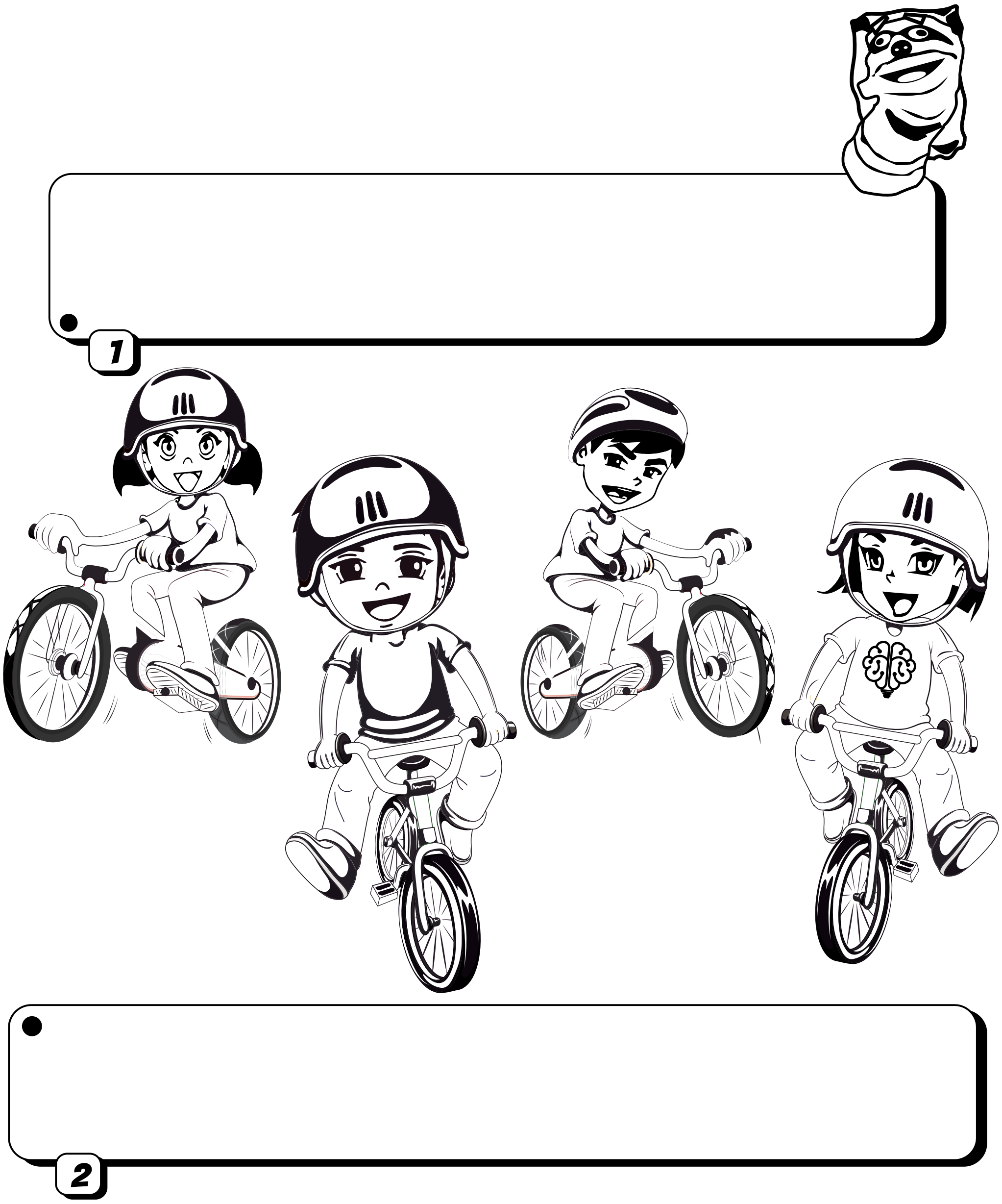
Source: Colouring Book [Book 1, Page 5A]

What does the second question mean?

? What does it mean? It is ‘Below in blue,’ ‘in below-blue’ or ‘below in the picture.’ How shall we select one of them and why can we say the selection might be reasonable?

< back to contents

Task 5B



Source: Colouring Book [Book 1, Page 5B]

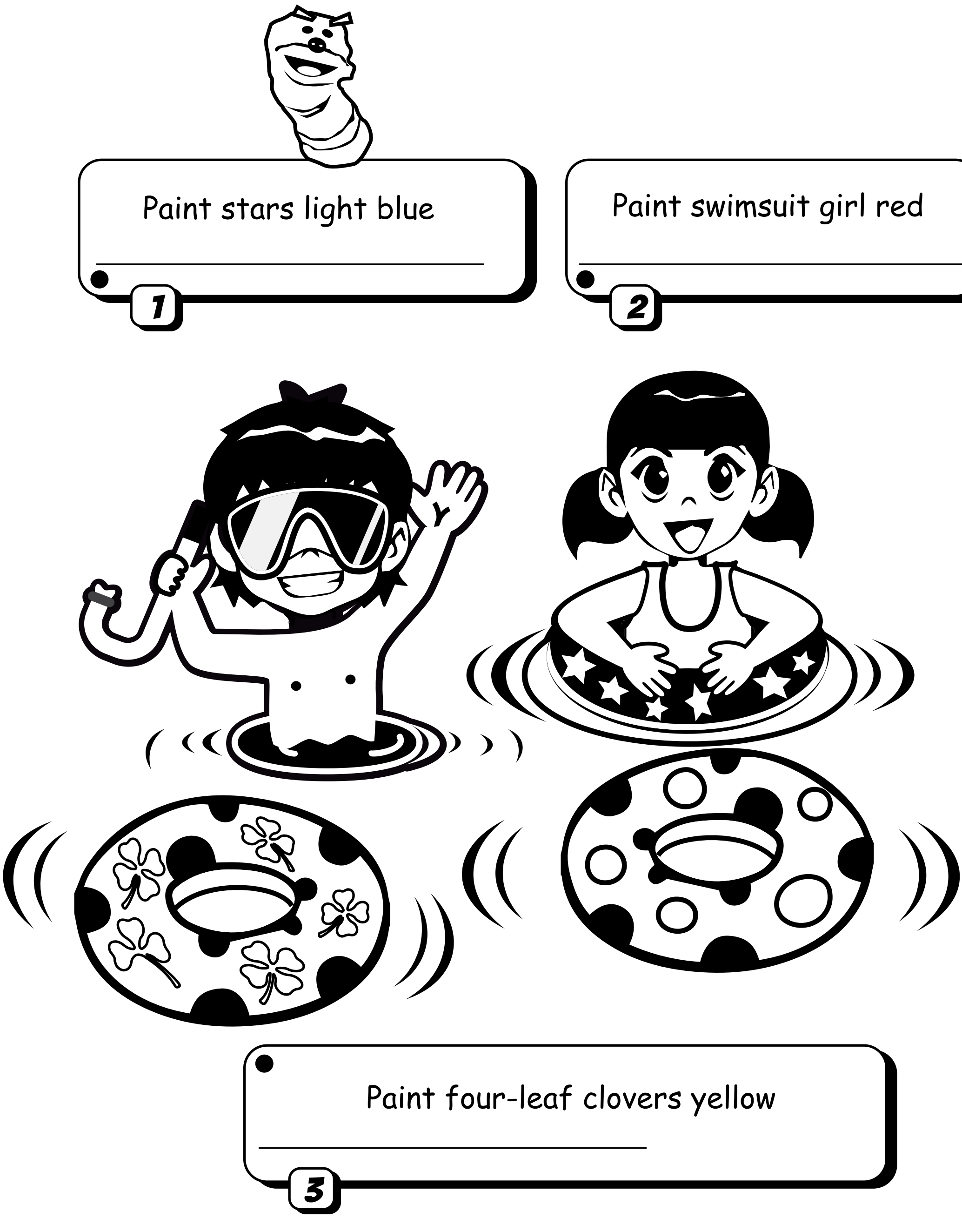
Let’s fill in the boxes by setting conditions by yourself.

- ? When you present in the whole class, what is the point of explaining to avoid misunderstanding.
- ? How do you change the conditions?
- ? What is the antonym and synonym of ‘below’?

Let’s explain the learning objective of these activities by using the following words: Interpretation of meaning reasonably.

1.6 Swimming

Task 6A



Source: Colouring Book [Book 1, Page 6A]

Let's discuss the painted result and find the different result depending on students. And discuss why the different painted result was produced?

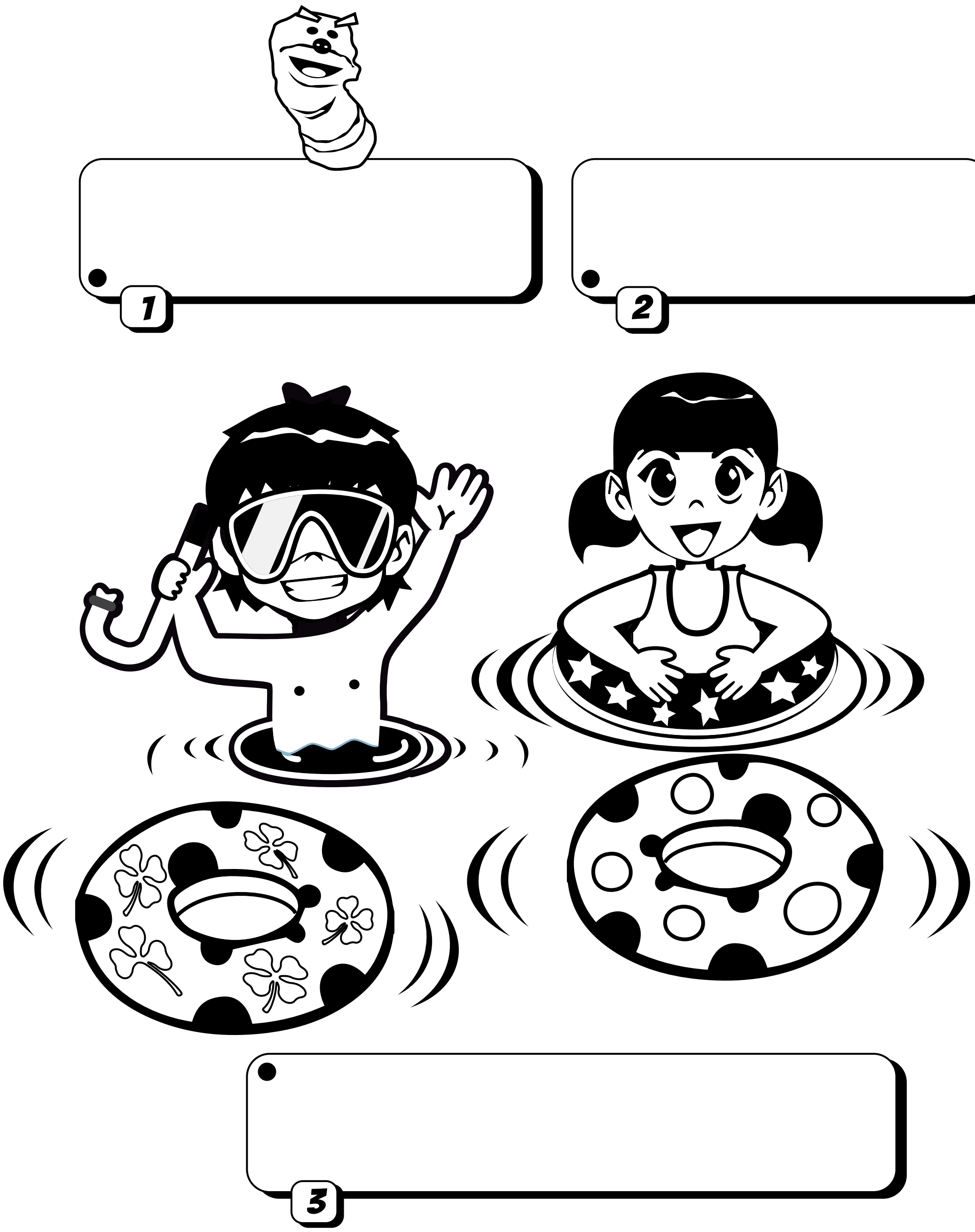
Please note, stars are not always drawing twinkling stars. In science-astronomy, stars are usually sphere-like circles.

? Which strategy did you choose?
Strategy 1: Read all the questions and then, paint.
Strategy 2: Read and paint each question in order.

? What is the difference between these strategies? Which one is better?

< back to contents

Task 6B



Source: Colouring Book [Book 1, Page 6B]

Let's fill in the boxes and then, discuss who's questioning in order is similar to Task 6A.

? If questions which produce the different result depending on selected strategy like Task 6A, it can be said to be similar questions.

Let's explain the learning objective of these activities by using the following words: Thinking forward and Thinking Backword, algorithm

1.7 Magician Show

Task 7A

1. Paint the jacket light blue

2. Paint the rabbit yellow

3. Connect the magic wand

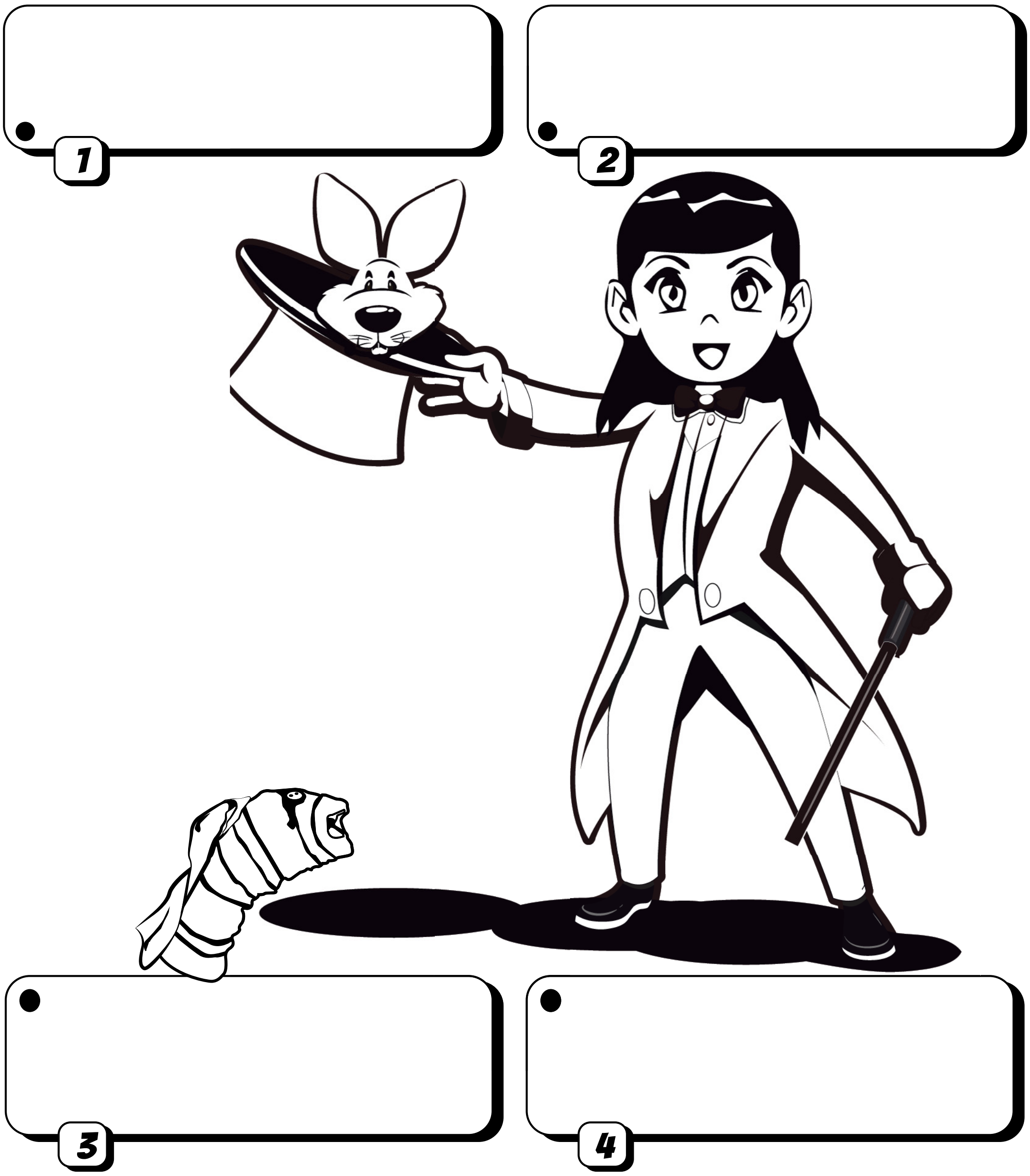
4. Paint the hat blue

Source: Colouring Book [Book 1, Page 7A]

1. Let's develop the story of magic in the ordered commands.
2. In the story, what is the function of 'the magic wand'? Is it a reasonable flow of story?

? 'Connect the magic wand to which' was not fixed. What we should make clear is that the function of the magic wand may change or transform something. While the audience looks at the tip of the cane and listens to the spelling by the Magician, Magician prepares something with another hand and so on. At the last moment, eventually, something happens or transforms. In this process, Audience surprised by the unexpected result from the perspective of the previous stage.

Task 7B



Source: Colouring Book [Book 1, Page 7B]

Let's fill in the blank boxes to illustrate something magic show.

? Is it possible to set the magic wand action at the first or last command?

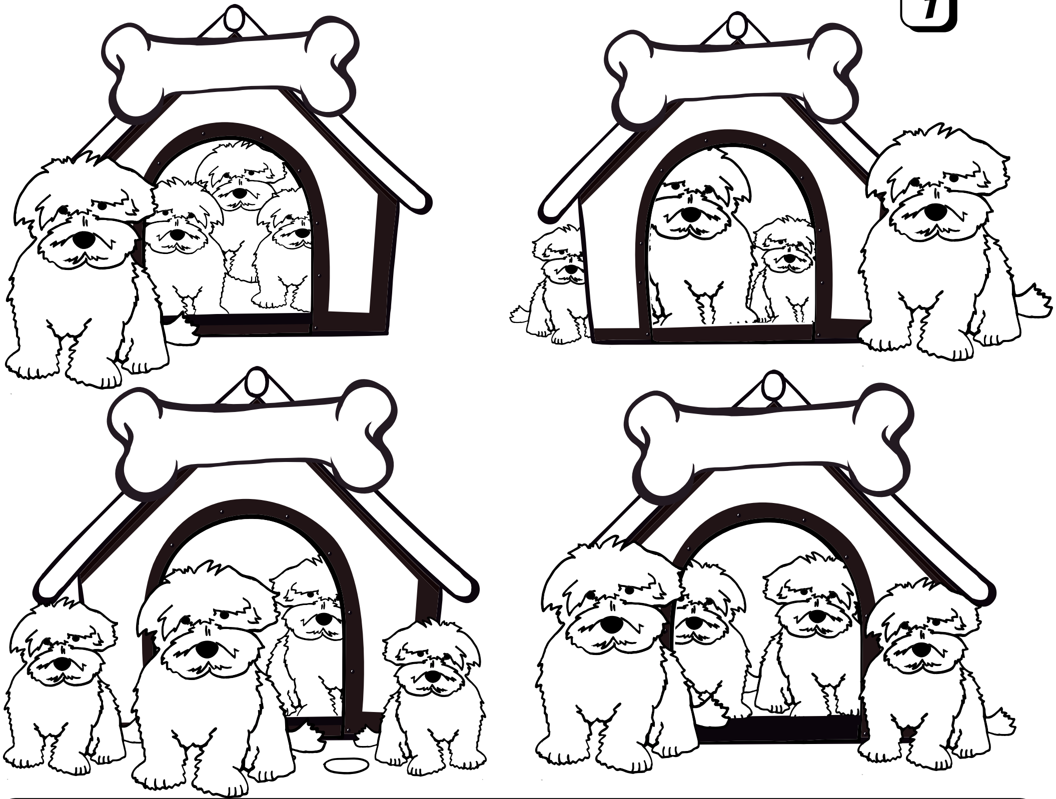
Let's explain the learning objective of these activities by using the following words: Algorithm, Subroutine (agent), Recursion

1.8 Dog Houses

Task 8A

Connect and paint red the house with more dogs in it

1



Connect and paint yellow the house with only one dog in it

2

Source: Colouring Book [Book 1, Page 8A]

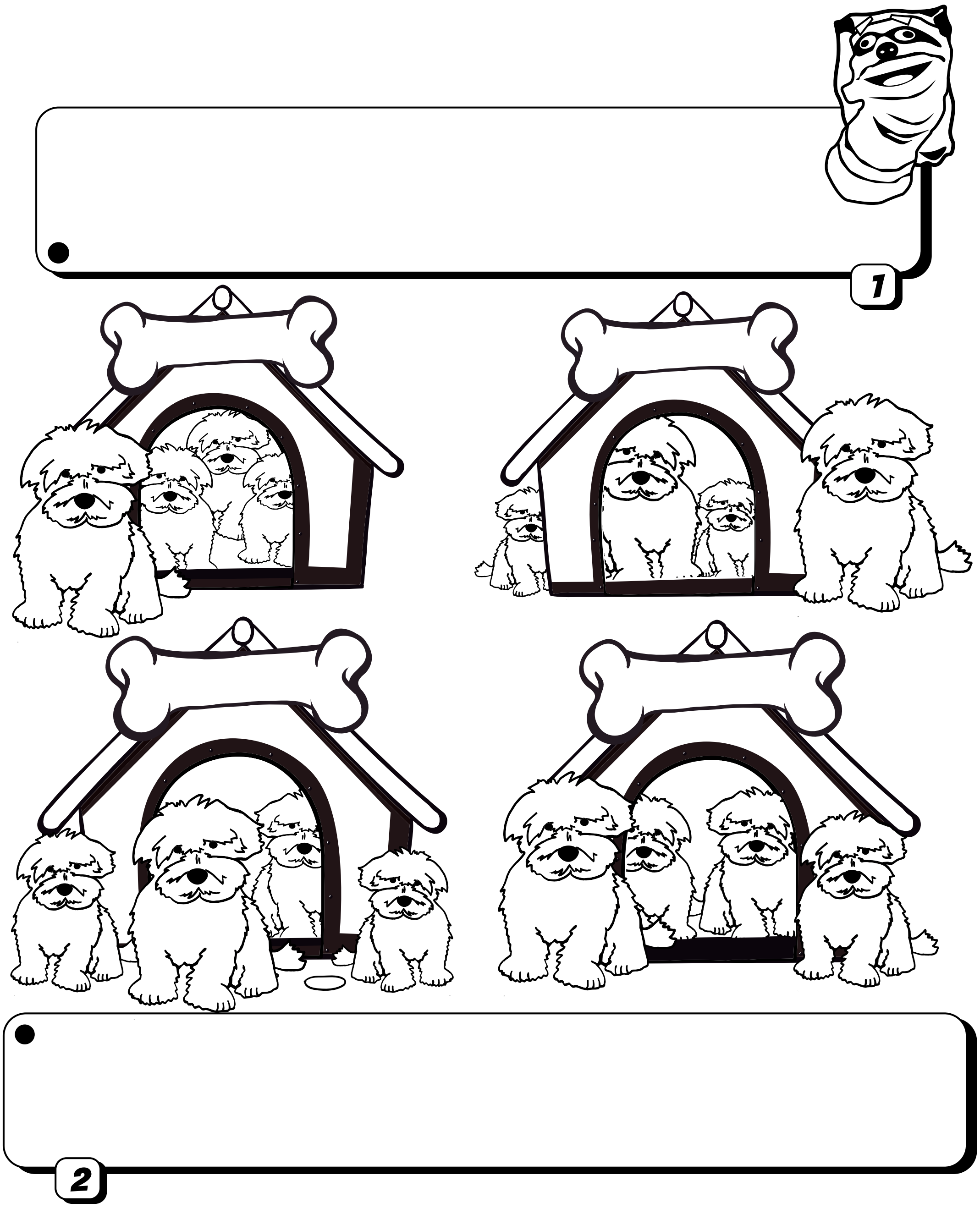
1. Let's paint and explain it to the others.
2. Let's explain every doghouse by using the word 'more' or 'only.'

? Discuss the keywords such as more and only.

? The number of outside dogs is and inside dogs is, thus ..... more than....

< back to contents

Task 8B



Source: Colouring Book [Book 1, Page 8B]

Let’s set new questions and pose them to the others.

- ? Let’s use antonyms such as Inside-Outside, Front-Back, and Big-Small.
- ? Let’s use antonym such as more or less,

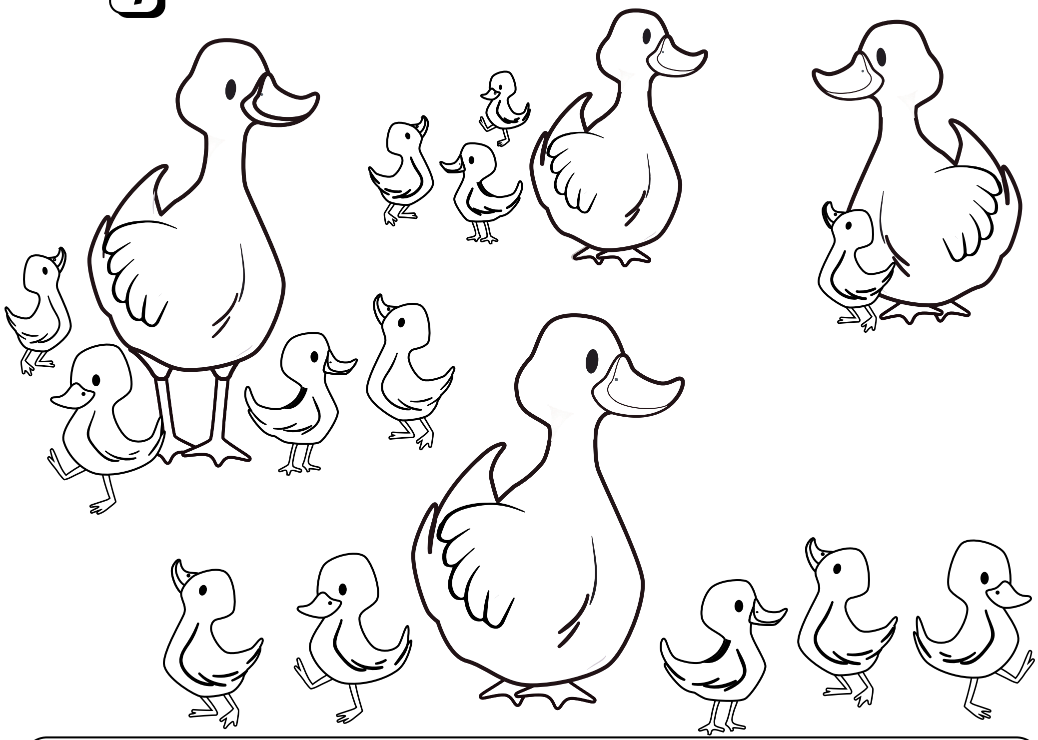
Let’s explain the learning objective of these activities by using the following words: Set and condition, includes, sub-set, and compare

1.9 Ducklings

Task 9A

Connect and paint yellow duck with most ducklings

1



Connect and paint brown the rightmost duckling

2

Source: Colouring Book [Book 1, Page 9A]

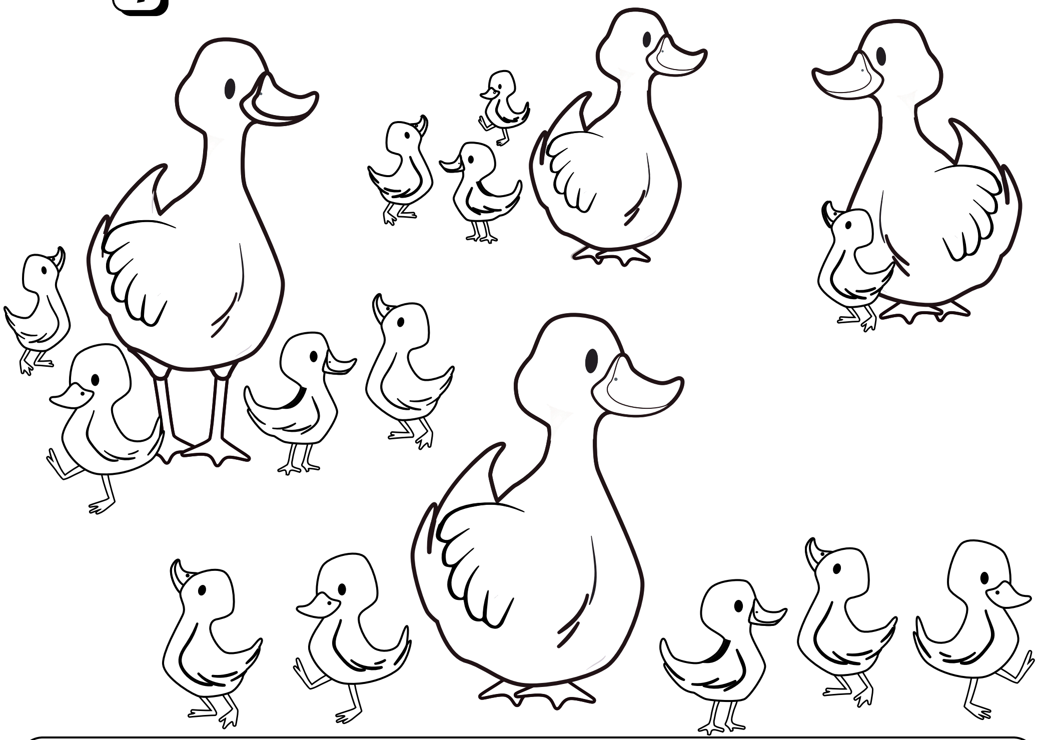
Let's answer and compare your answer with others' answers. What do you find with comparison.

- ? What does it mean 'duck with most duckling'?
- ? Compare the meaning of 'most' in 'most ducklings' and 'rightmost'.
- ? Do you think the 2nd question must follow the 1st question? If not?
- ? Connect A with B. Which are A and B?
- ? Connect A and B. Where is B?

< back to contents

Task 9B

1



2

Source: Colouring Book [Book 1, Page 9B]

1. Let's set the questions and ask them to your friends.
2. If their answer is not the same as yours, please listen to their idea and discuss the difference.

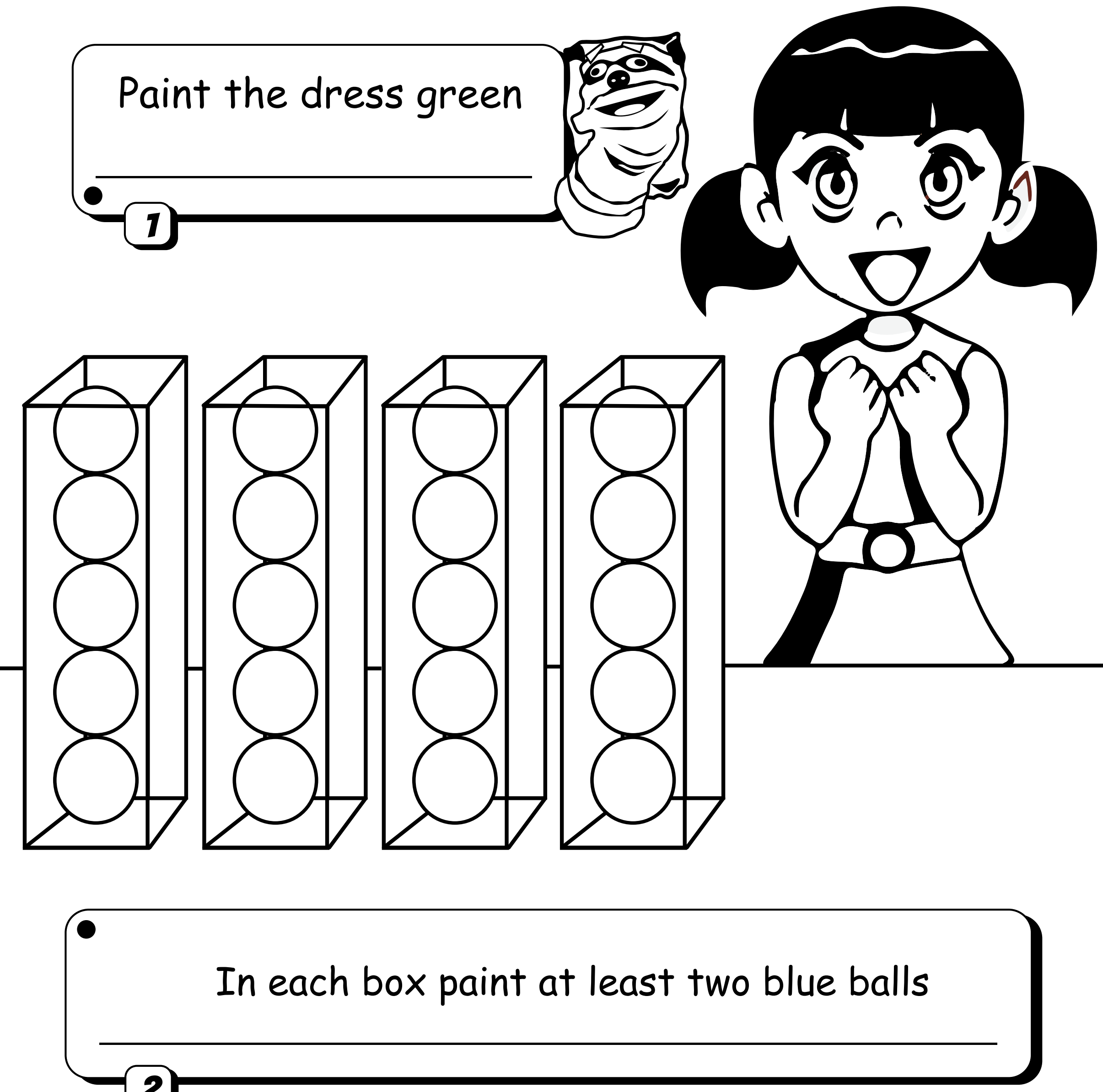
? How do you change the conditions of Task 9A?

? Discuss the keywords which you preferred and order of questioning and find why it produces different paintings for the same questions.

Let's explain the learning objective of these activities by using the following words: Set and condition, compare, ordering, algorithm, position, reasonableness

1.10 Ball Painting

Task 10A



Source: Colouring Book [Book 1, Page 10A]

1. Let's design a beautiful picture on your unique painting based on the given condition. Then, present it to each other with an explanation.
2. Let's explain your unique manner without showing the original picture itself to your friends and the friends re-present the picture based on your explanation. And compare your friend's picture with your original picture.

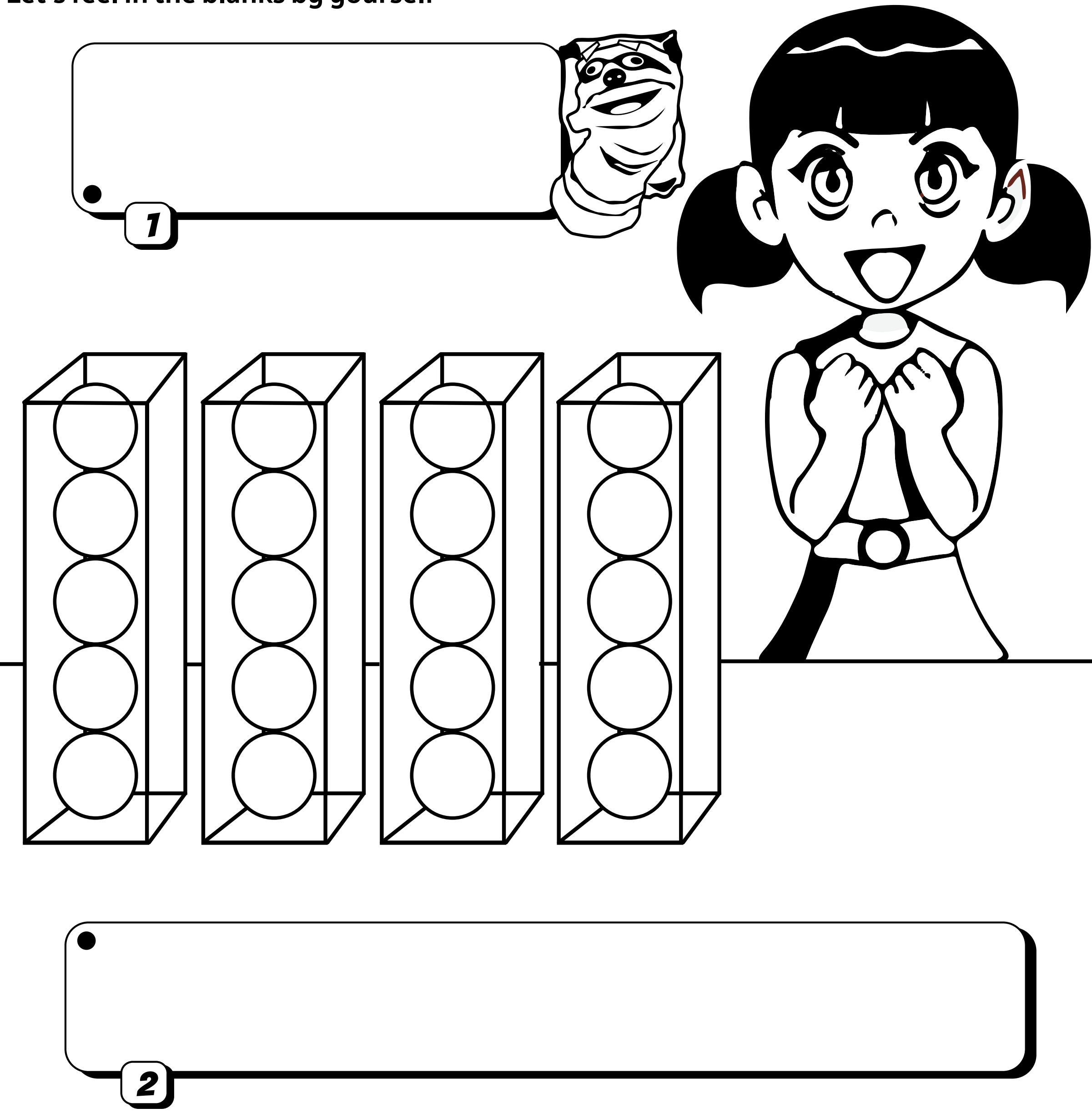
? Through the comparison with others, let's think whose explanation is most understandable for you and appreciate whose one is really beautiful or unique for you?

? How do you use the condition of 'at least' in your painting?

< back to contents

Task 10B

Let's feel in the blanks by yourself



Source: Colouring Book [Book 1, Page 10A]

1. Let's set new conditions for painting which produce beautiful pictures for you.
2. Let's inform the others, and what do you find after comparing your one with others products.

? How do you change the questions written on the picture on Task 10A. If you learned from others, please refer who's ideas you influenced.

? How your meaning of beautifulness has changed through these activities.

Let's explain the learning objective of these activities by using the following words: Position, ordering, pattern, algorithm, barbal explanation, change condition

1.11 Fish Tank

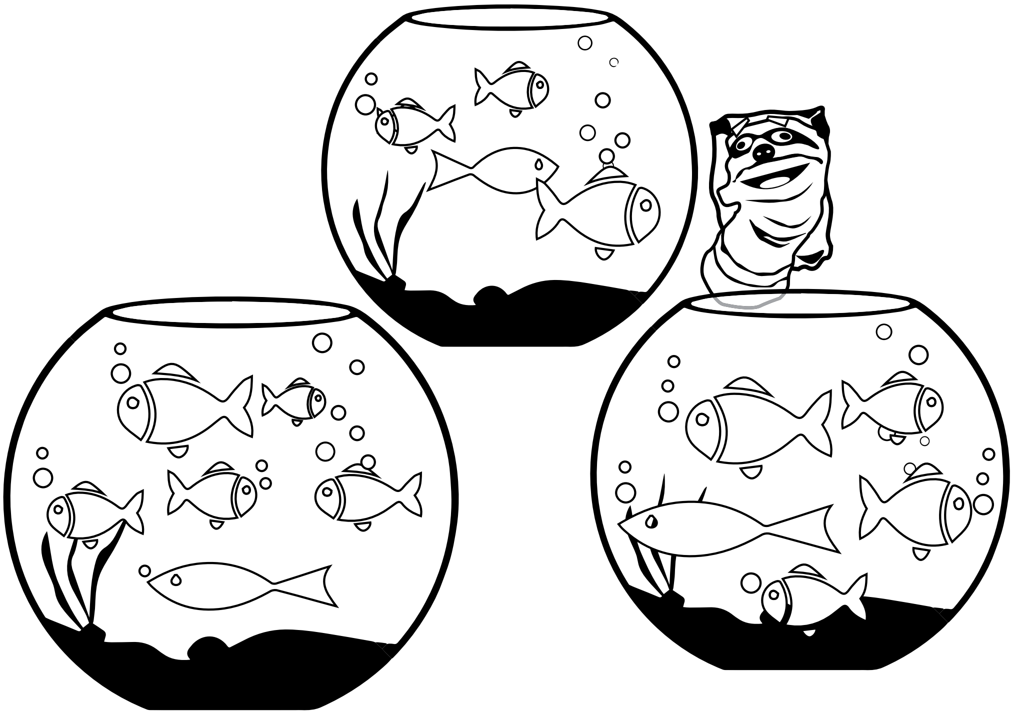
Task 11A

In each fish tank paint the tails of at least two fish

1

Connect the fish tank with least bubbles and paint the water

2



Paint blue the eyes of all the fish in the fish tank with more fish

3

Source: Colouring Book [Book 1, Page 11A]

In every question, Let’s paint and discuss your painting with others. When the others' paintings are not like you, let’s discuss the reason.

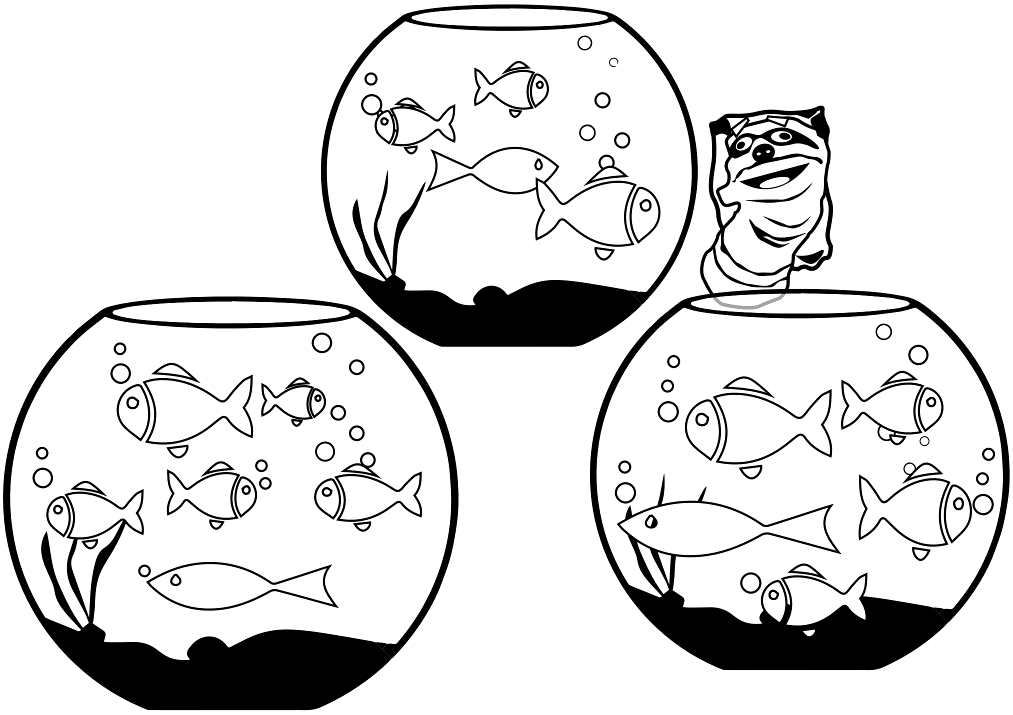
- ‘At least two’, what does it mean?
- ‘Least bubbles’, what does it mean? Does it mean smallest?
- What is the difference between 'tank with more fish’ and ‘tank with most fish’?

< back to contents

Task 11B

1

2



3

Source: Colouring Book [Book 1, Page 11B]

Let’s set a new instruction for painting and pose it to the others. How different are others' paintings and why?

? Do you use the ways of questioning which were learned at Task 11A?

? For changing the questions, what words do you prefer instead of written in Task 11A?

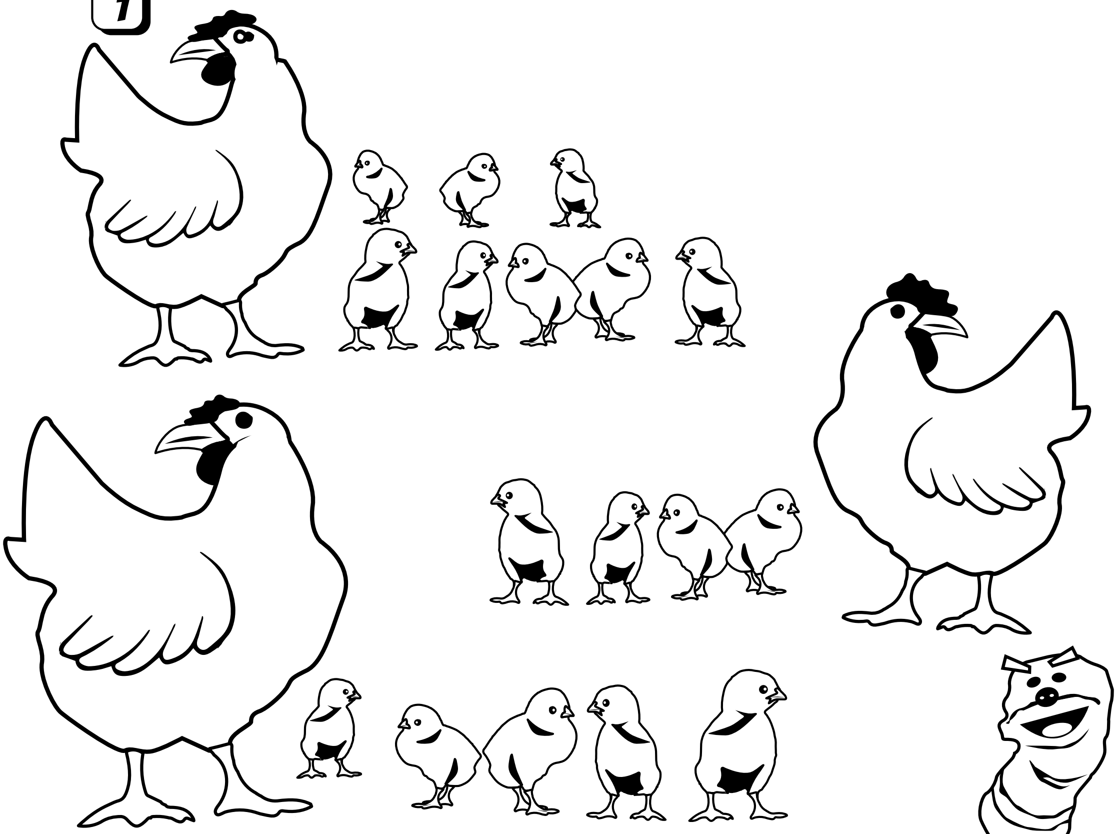
Let’s explain the learning objective of these activities by using the following words: Set, condition, parameter, what if and what if not

1.12 A Flock of Chickens

Task 12A

Connect and paint red the hen with most chicks

1



Connect and paint yellow the smallest chick of the largest hen

2

Source: Colouring Book [Book 1, Page 12A]

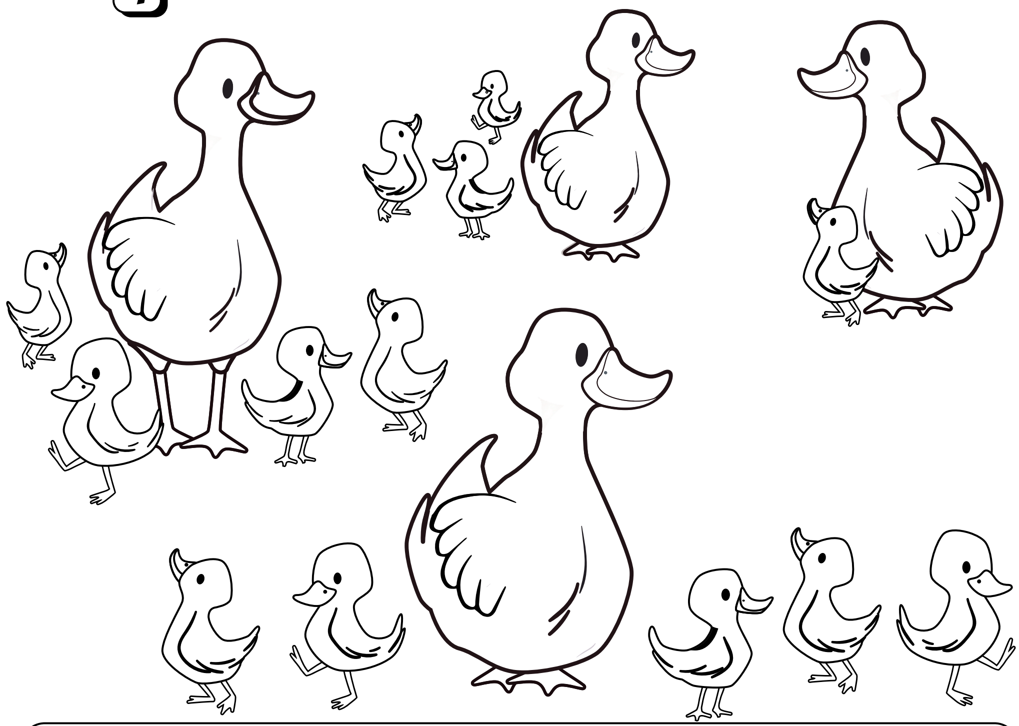
1. Let's see and explain what you find before reading questions. After that, read each question and paint. Do you find anything new when you compare your finding before and after your answer?
2. If you begin to answer from the second question, are the results of paintings the same as answering from the first question?

? When do we use the comparison words 'most,' 'smallest' and 'largest'? Let's explain it by using the picture. Let's discuss why we can say it as most, smallest or largest.

? In your explanation, within which group you are mentioning. If we change the referring group, what will happen?

Task 12B

1



2

Source: Colouring Book [Book 1, Page 12A]

Let’s pose the new questions to the others.

? When you set the questions based on what you learned at Task 12A, how do you pose the question.

? When you set the questions without considering what you learned at Task 12A, how do you pose?

Let’s explain the learning objective of these activities by using the following words: Set, condition, compare, ordering, what if and what if not

1.13 Hidden Card

Task 13A

Connect and paint red the object where the card is hidden

1

Source: Colouring Book [Book 1, Page 13A]

1. Let's read each bubble and consider the possibility.
2. If you find it, let's explain to the others why you guess there.

? Let's discuss the differences between the following: 'A book' and 'books,' 'closer' and 'closest,' and 'in' and 'on

Task 13B

Source: Colouring Book [Book 1, Page 13B]

1. Let's set your hidden object by yourself and produce a set of conditions to reach.
2. Pose it to your friends. Their answer is the same as yours or not. If not, why do different answers appear?

? Let's enjoy questioning the others and discuss various ways of posing questions to distinguish a set of objects. When do you feel originality and ingenuity in the ways of questioning?

Let's explain the learning objective of these activities by using the following words: Set and Sub-set, condition, what if and what if not, belonging and not belonging

1.14 Hidden Coin

Task 14A

Source: Colouring Book [Book 1, Page 14A]

1. Let's read each bubble and find the place of the coin.
2. Shall we have to use all four bubbles to find the place?

? Could you categorise four bubbles into two categories? Let's naming for each category to distinguish the categories

? If you use the following words, how the meaning may change?
'Top' and 'Not Top,' 'Near' and 'Not Near' or 'Far,' 'Under' and 'Not under' or 'Over'

Task 14B

Source: Colouring Book [Book 1, Page 14B]

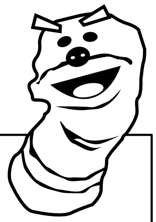
1. Let's set your hidden object by yourself and produce a set of conditions to reach.
2. Let's enjoy each other's work and apply each of others' ingenuity.

? On the setting conditions, do you use the condition categories which were discussed at Task 14A? Do you find further categories?

Let's explain the learning objective of these activities by using the following words: Set and Sub-set, condition, what if and what if not, logic

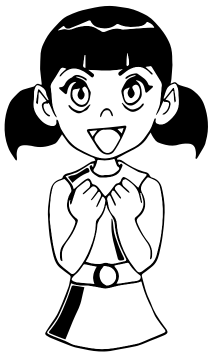
1.15 Mixed Triangle

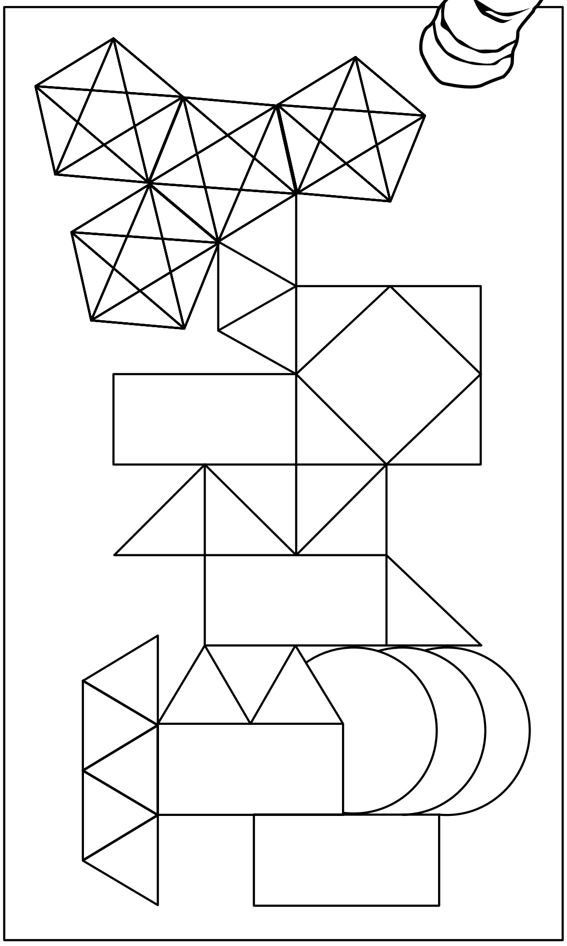
Task 15A



Connect and paint your region

1





Describe a place from another region you have visited

2

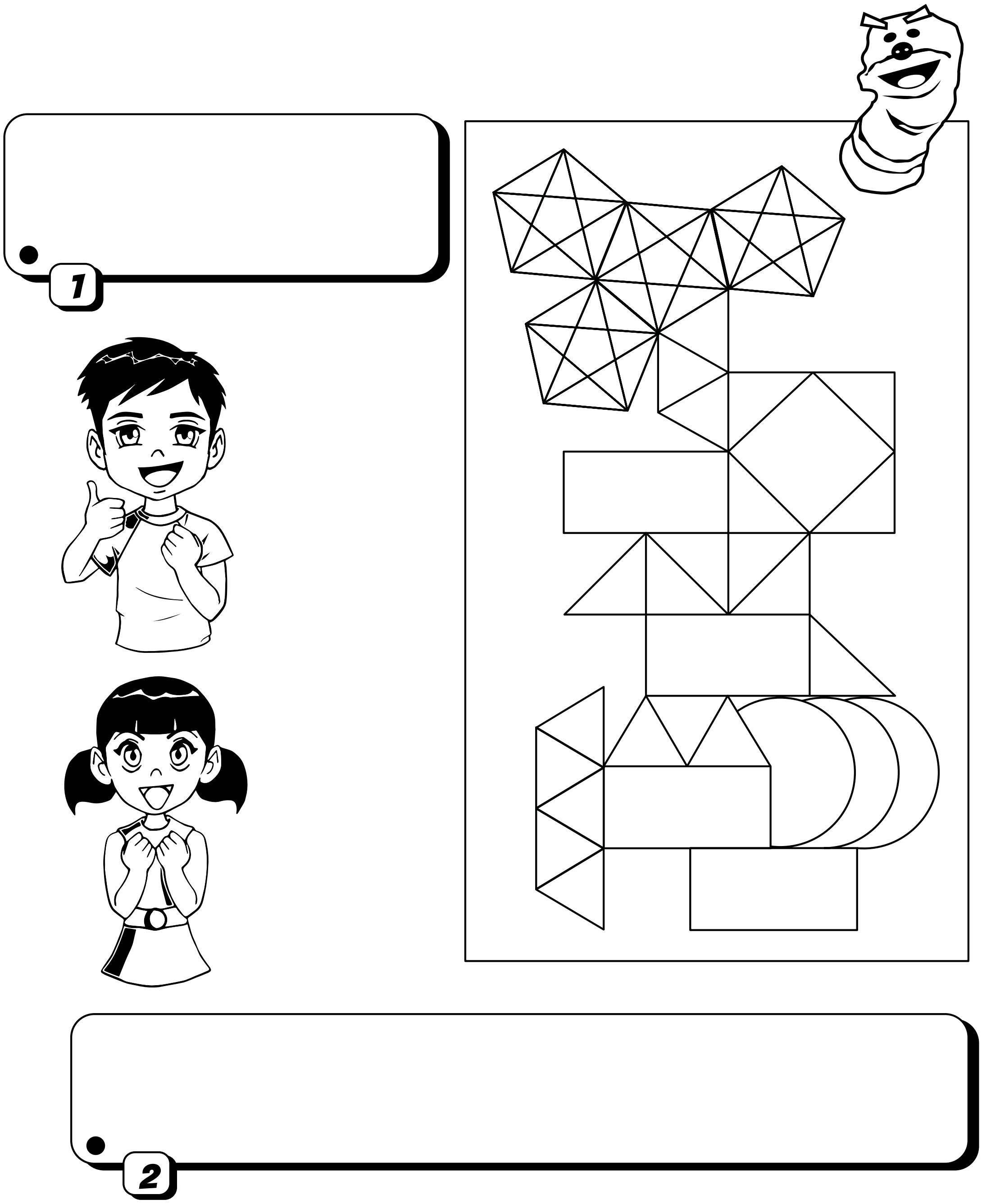
Source: Modified from Colouring Book [Book 1, Page 15A]

1. Explain to others why the chosen triangles are the smallest?
2. How many colours do you need to fill each neighbor in a different colour?

? How many unit shapes do you find in the picture?

? In minimum, how many colours do you use for filling in all?

Task 15B



Source: Modified from Colouring Book [Book 1, Page 15B]

Let's fill in the new questions based on the experience of Task 15A.

? If your focused shapes are a combination of other shapes, let's think about the way to use the unit shape.

Let's explain the learning objective of these activities by using the following words: Combination of Unit shape, Order of layer, Attribute of shape and property of figure, Minimum

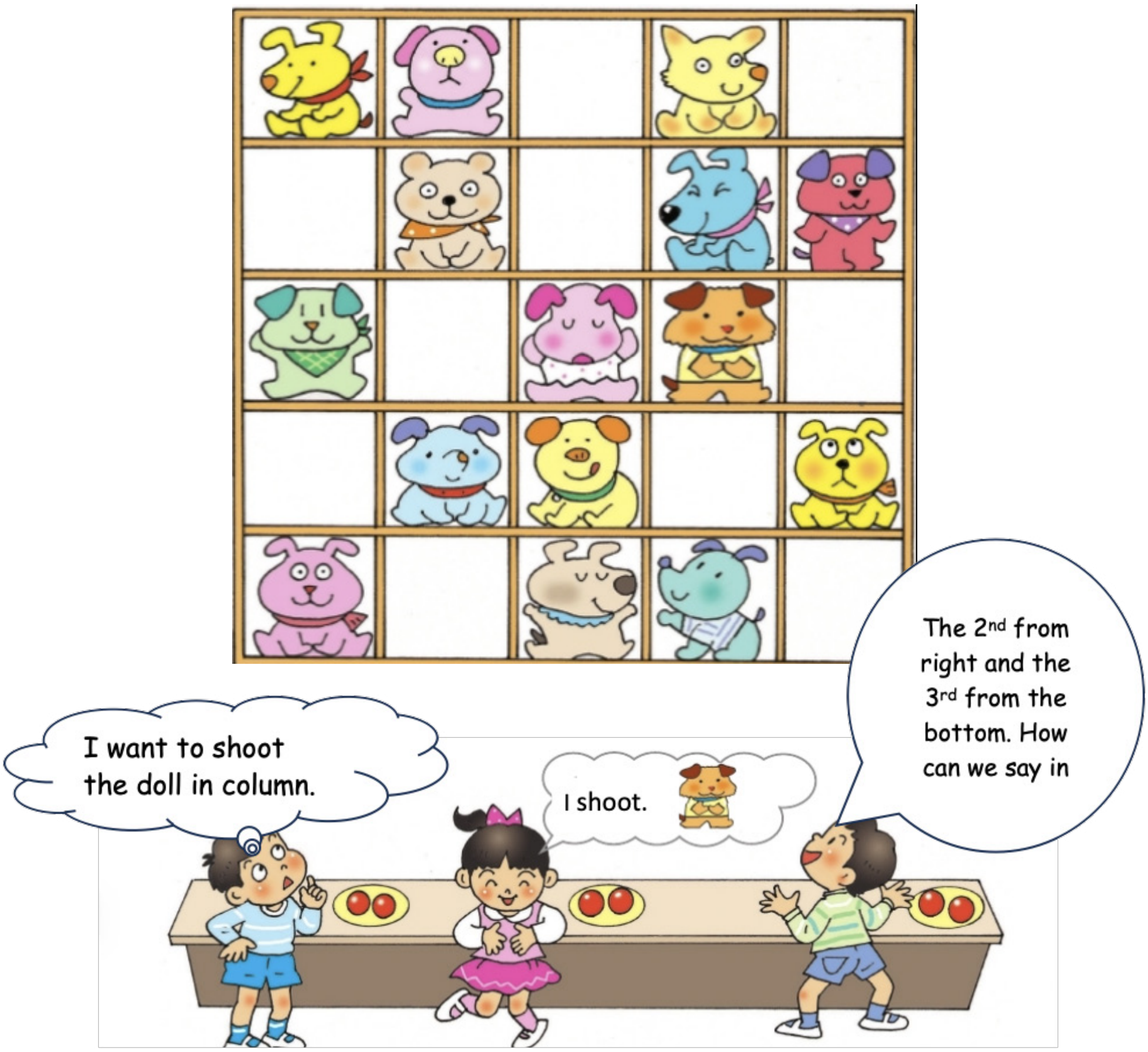
CHAPTER

2

< back to contents

In Mathematic Classroom

2.1 Dolls shooting Game Task 1A



Source: Study with your friends: Mathematics for Elementary School, Gakko Tosho (English Edition)

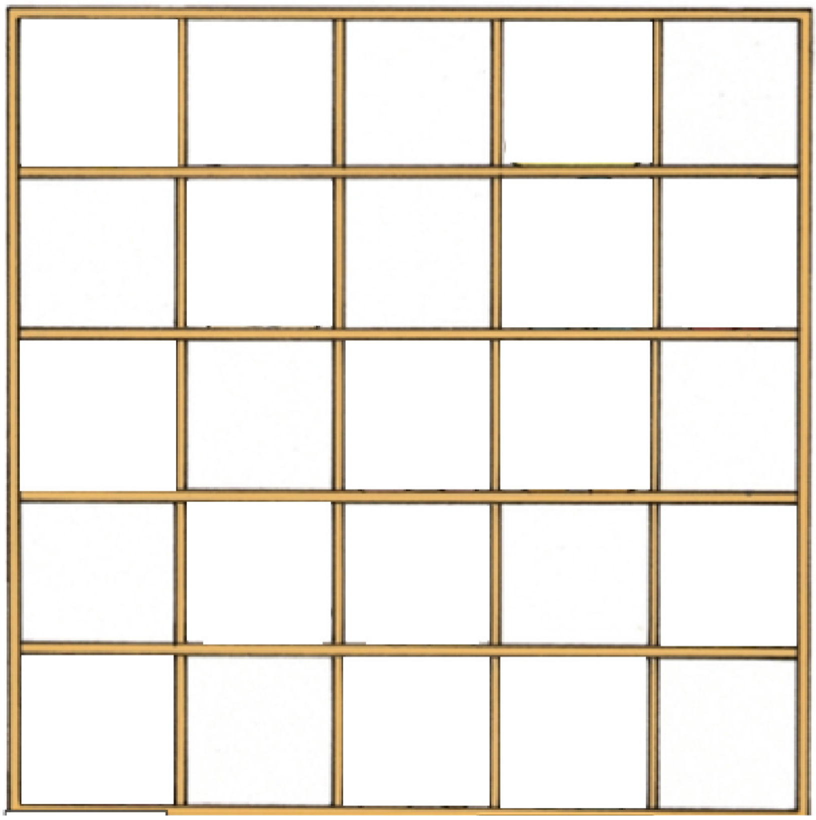
1. Could you explain the location of the doll that you would like to shoot by ball?
2. How do you share the location with your friends?
3. Which location is easier to shoot?

? Ambiguous words such as ‘there,’ ‘over there,’ ‘near dogs,’ and so on, are never understood by the others without pointing by finger and so on.

? Even pointing by finger, if the locations of children who are explaining are various places, we cannot fix the location exactly.

Task 1B

Let's imagine the location of the doll in the frame by yourself in your mind. And then, ask your friends to locate it by your explanation without showing the location itself.



Source: Study with your friends: Mathematics for Elementary School, Gakko Tosho (English Edition)

? Did your friends locate the same as your expectation?

? What terms and explanations are useful for explaining the location via a phone call.

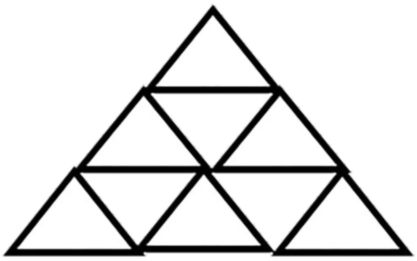
Let's explain the learning objective of these activities by using the following words:

Through explaining of the location using words such as 'from top', 'from bottom', 'from left side', 'from right side', 'rows and columns' and so on, and translate them to the other words, students are able to locate the position. 'Third row' and 'fourth column' is a way to explain the location, however children need to take care of the facing from the front, left or right.

2.2 Triangle Arrangement

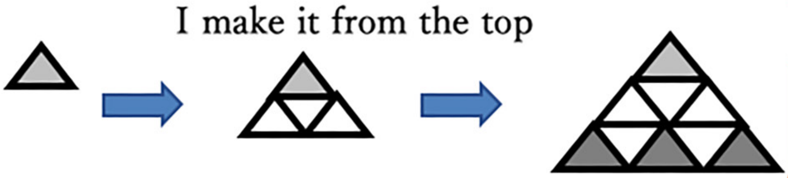
Task 2A

How do you develop following picture by using the unit shape △.



Let's explain the way. Is it only one way?

I make it from the top



I make it from the left side.

? ? ?

Source: Study with your friends: Mathematics for Elementary School, Gakko Tosho (English Edition)

1. Let's explain your original way to others.
2. Which way is most simple to explain the way to others?
3. Let's colour the unit shape to show the way clearly.
4. Let's put the number in the unit shape to show the way.

What does it mean left side? There are two possible interpretations, right?

? On 1., There are various possible ways. Even though the same way, there are variety of ways to explain, right?

? On 2., To explain the way through the phone without camera view, we have to distinguish which objects, place and order such as 'at first,...' and so on.

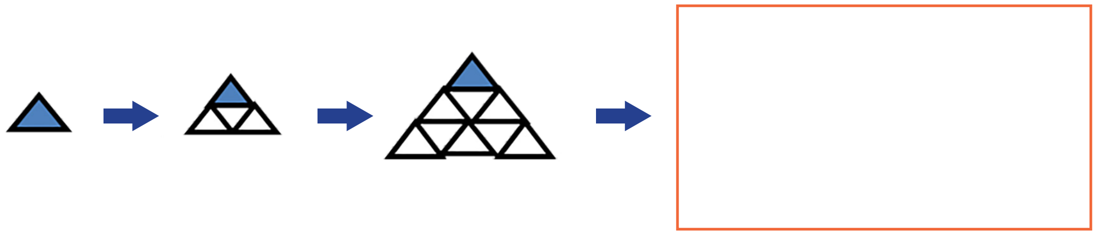
? On 3. and 4., Colouring and numbering are idea to explain however we have to distinguish first and number one and so on.

Task 2B

On Task 1, answer the following.

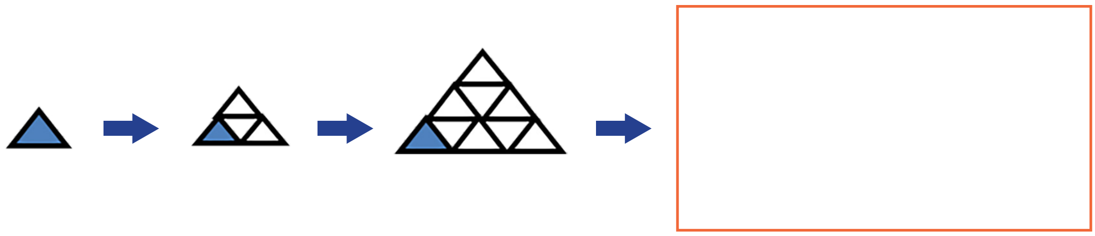
1. Following are developed from the top. What shape comes fourth?

First Second Third Fourth



2. When developing from the left side, what shape comes fourth?

First Second Third Fourth



Source: Study with your friends: Mathematics for Elementary School, Gakko Tosho (English Edition)

Task 2C

Let's pose similar questions by using other unit shape such as □

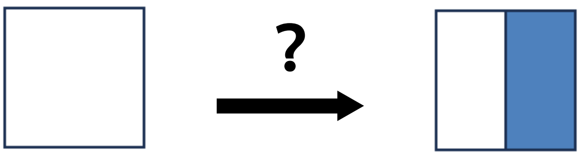
? On Task 2, it is possible to ask without Task 1, however it depends on the ways of interpretation, first step, second step and third step.

? On Task 2, it changes depending on what is left and order.

Let's explain the learning objective of these activities by using the following words:
- How to express the process by the steps, instead of just adding each piece one by one, for creating the beautiful, arranged pattern.
- Listening to others' way of explanation and supporting them by adding necessary words in case.

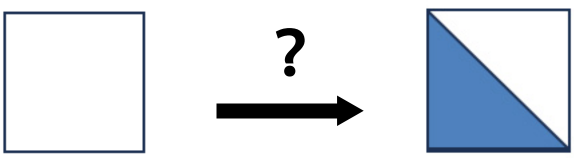
2.3 Square Folding

Task 3A



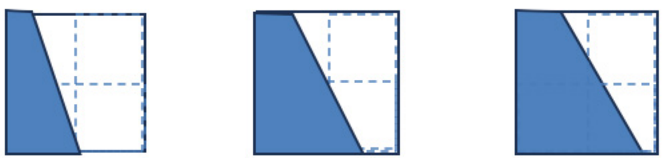
Hamid would like to get a half of the square sheet.

- How did he fold the paper?



Mary found another way to get the half of the square. Could you explain her folding?

- Hamid's half and Mary's half of the square are different in shapes. How do you explain that both of them are the same half?

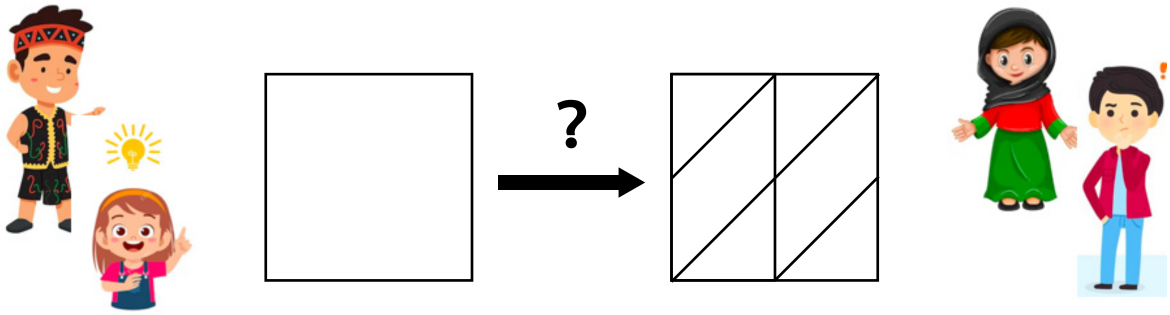


- Cai said 'All three are half of the square.' Hamid and Mary said 'No.'
- What do you think?

? To demonstrate the half, we can use exactly overlapping. If not, we are not sure.
- Can you use scissors to explain that 'Hamid's one and Mary's one are the same half of square'?
- We can cut the square sheet by using the folded line. When a square is given and you are allowed to cut one time only, how many times do you fold the square?

Task 3B

Let's pose a set of questions to your friends to get the half of the square!

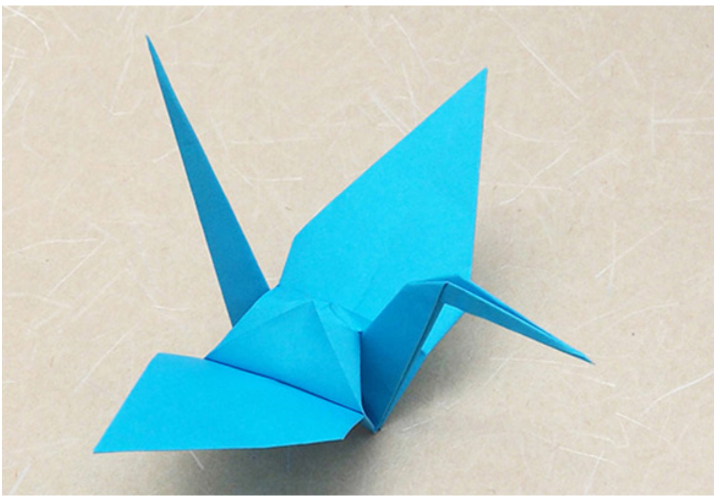


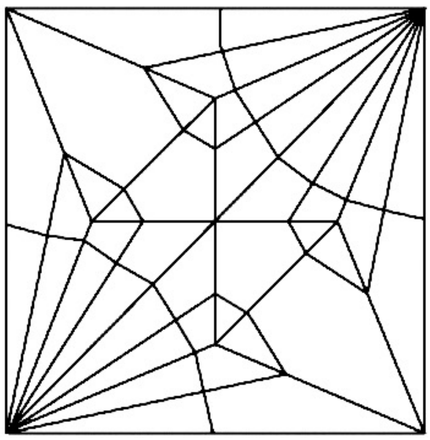
? How shall we set the situation that students would like to explain the following by and for themselves:

- Process of folding using four vertices of the square.
- How shall we define the half of square and how shall we confirm it as a half.

Let's explain the learning objective of these activities by using the following words:

- Half in Action: develop explanation for operational definition, rule for translation among lines, folding and cutting, overlapping, pattern and symmetry.
- Algorithmic Thinking: order of folding, how many times of folding or cutting, generalisation and specialisation.
- Reasonable and critical thinking while respecting and appreciating others: imagine reasonableness of others saying. If it is true, what will happen? Can we generalise?





2.4 Secrets in the multiplication table Task 6A

Let's fill in the multiplication table.

	1	2	3	4	5	6	7	8	9
1									
2		4							
3									
4									
5						30			
6									
7									
8		16							
9									

Source: Study with your friends: Mathematics for Elementary School Gakko Tosho (English Edition)

1. Complete the blanks in the table.
2. How did you fill?
3. After filling in all the blanks, let's observe the table. If you find any, pose it as a question to your friends.
4. For proposing your findings with your friends, as the rule of multiplication table to the whole class, planning the way of presentation, which is easy to understand.

? For finding the rules of multiplication table, let's see the followings:
- Relationship between a number in the table and next number in the same row.
- Compare the same numbers.
- Relationship between rows.
- Relationship between columns.

? For explaining the rules which you found, let's see each number in the table, as the answer of multiplication. For example, if the number in the table is '16', it might be the answer of multiplication such as '2 x 8' or '4 x 4.'

Task 6B

Nisakorn's group prepared the following for their presentations.

2	2	4	6	8	10	12	14	16	18
3	3	6	9	12	15	18	21	24	27
5	5	10	15	20	25	30	35	40	45

2	2	4	6	8	10	12	14	16	18
5	5	10	15	20	25	30	35	40	45
7	7	14	21	28	35	42	49	56	63

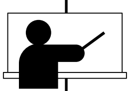
4	4	8	12	16	20	24	28	32	36
5	5	10	15	20	25	30	35	40	45
9	9	18	27	36	45	54	63	72	81

Source: Study with your friends: Mathematics for Elementary School Gakko Tosho (English Edition)

- Can you imagine what rule her group found?
- How many examples do we need to explain the rule? And why?
- Can you explain why the rule is true by using a stamp sheet?

Task 3

Let's prepare your presentations for your findings.

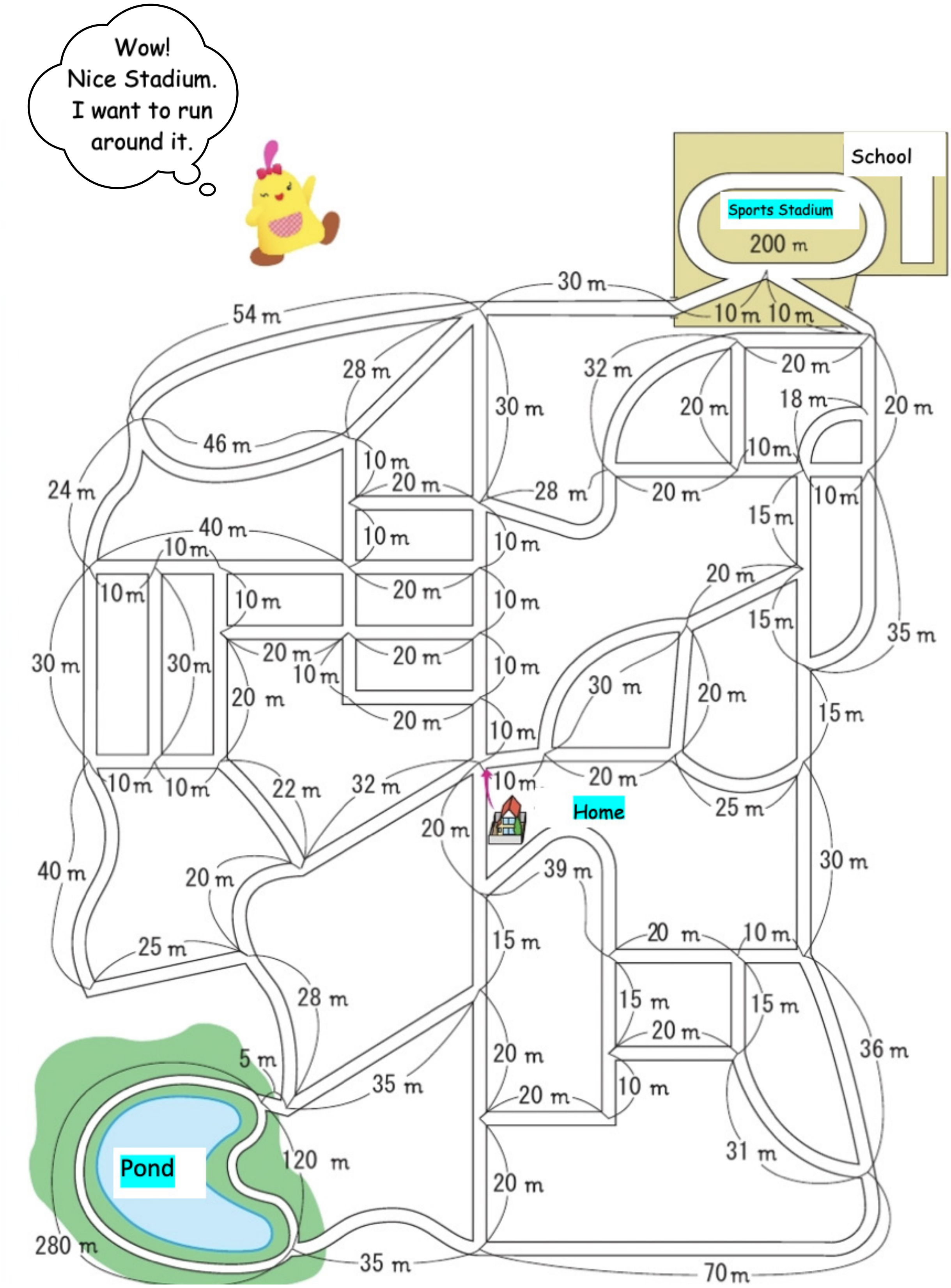


Let's explain the learning objective of these activities by using the following words:

- Finding the pattern on the multiplication table and appreciate the world of multiplication as a number structure without referencing real-world situation.
- Think inductively and analogically and explain the finding deductively.
- Imagine others who are not well-understood, and consider the ways of understandable explanation using understandable representations.

2.5 Running Route Design

Task 5A



Source: Study with your friends: Mathematics for Elementary School Gakko Tosho (English Edition)

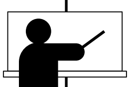
< back to contents

Design a running route with the following conditions.

1. Start from the house.
2. Return to the house at the end.
3. The total distance is less than or equal to 1 km.
4. Colour running route with red.
5. Share your route with the whole class.

Task 5B

Let's create a new set of conditions for designing a running route.



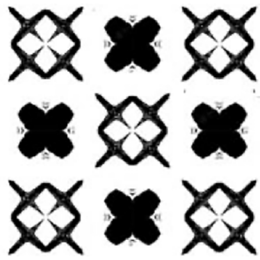
Let's explain the learning objective of these activities by using the following words:

- For learning the ways of setting conditions on problem posing on the situation, Task 1 is prepared.
- 'What if' and 'What if not', is not only used in addition but also in multiplication.

2.6 Design with Patterns

Task 7A

Let's see the right picture.
How many components do you find on this design?



Task 7B

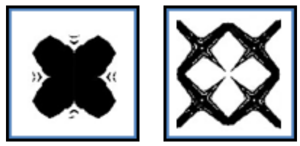
Hamid found the following two tiles in the picture.

And asked Mary 'How many of each tile do we need for designing the picture?'

Mary named them 'Cross' and 'Darts' and began to design.

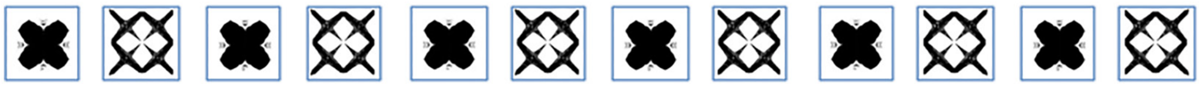
Let's design by yourself by using the parts.

Cross Darts

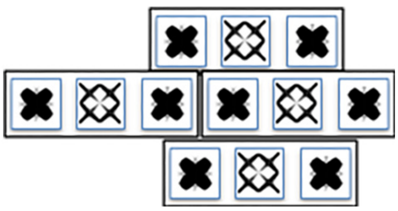


Task 7C

Mary printed each tile on the glue-tape in order as shown below:



For designing the picture, where shall we cut this tape and how to paste each on the board. Please plan and then explain the way to the others and compare.



?

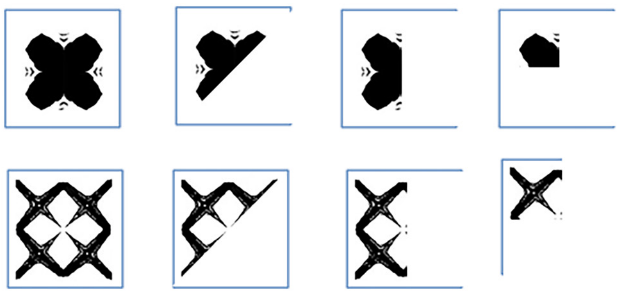
? There are various components.
- How many components do you find?
- There are various possibilities for pasting, however if we cut it into too many pieces, it is not easy for arrangement of pasting, the result will become undesirable.
- How shall we develop the tape for easier pasting?

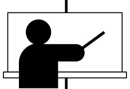
Task 7D

Let’s design the wallpaper!

- How shall we develop the wallpaper which has a beautiful symmetrical design and connects well on each other's edges while keeping the design?

Following are samples for designing parts and wallpaper size, in case you would like to use it.



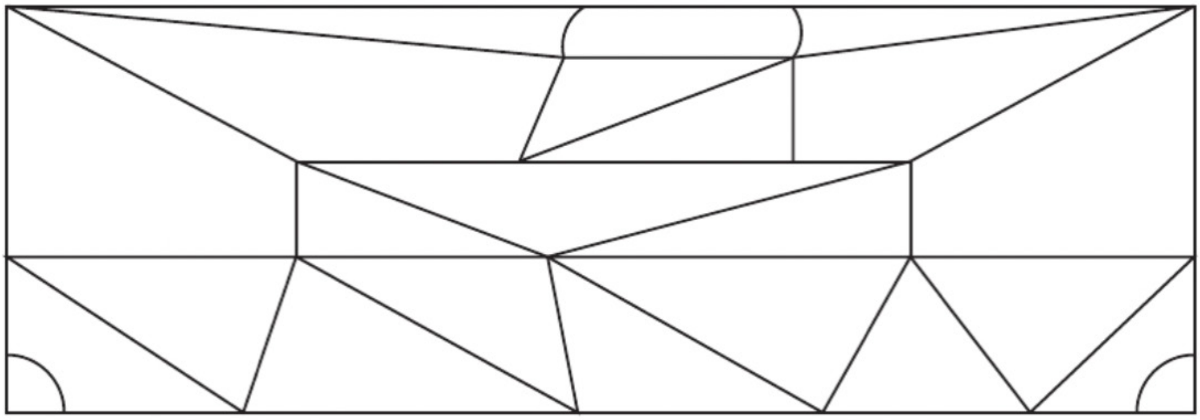


Let’s explain the learning objective of these activities by using the following words:

- Explain the beautifulness from the perspective of invariant pattern and symmetry and appreciate others’ ways of explanations.
- Discuss the reordering activity for clearly explaining the patterns.
- Promote the development of appropriate algorithm for a sequence of procedures to produce the design from the components on the tape.
- Use symmetry to design the wallpaper.

2.7 Tessellate! Task 9A

There are a lot of triangles.



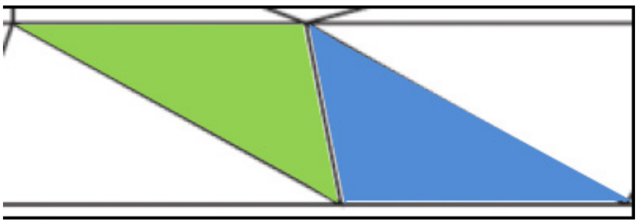
Source: Study with your friends: Mathematics for Elementary School Gakko Tosho (English Edition)

Various shapes such as triangles are used for developing this tessellation.

1. Many different triangles are used. Let's colour each triangle to distinguish it from its neighbours. You can use four colours for colouring: red, green, yellow, and blue. When colouring, please consider the way to distinguish because it looks just like quadrilaterals if you use the same colour for neighbour triangles.
2. Please show it to the others, and discuss whether it is well distinguished or not.
3. Many quadrilaterals can be found if you choose two triangles.

In there, can you find any parallelograms like the following sample? In these quadrilaterals, how can you distinguish parallelograms and other quadrilaterals which are not parallelograms?

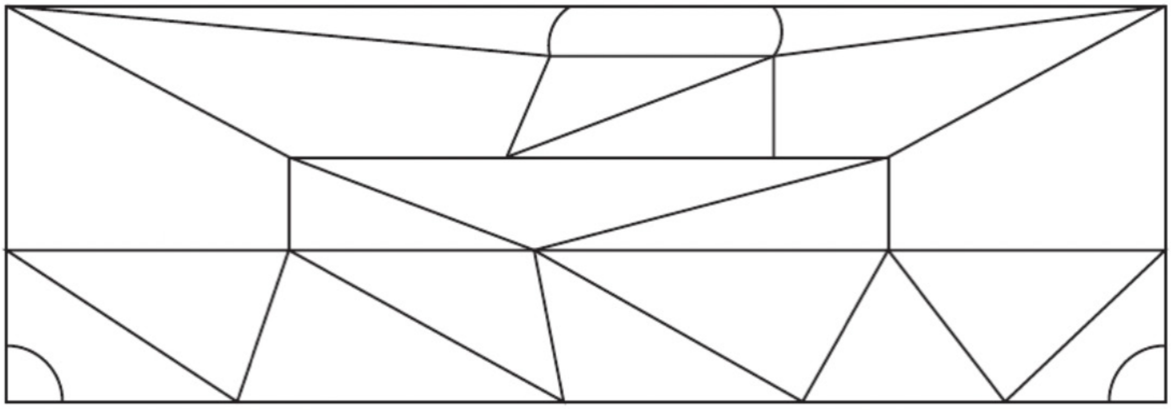
Sample:



? From triangles, we can develop various polygons such as quadrilaterals.
To produce parallelogram from two triangles, which triangles shall we choose?

Task 9B

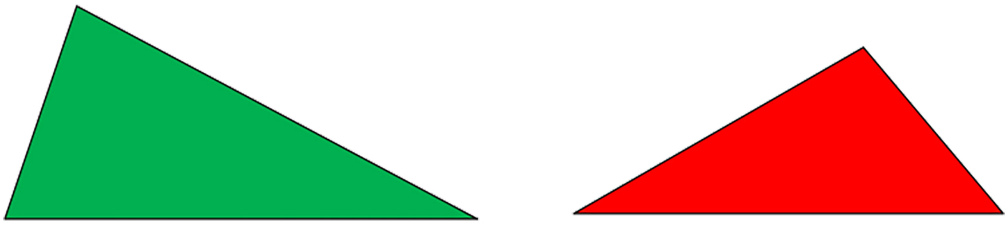
There are many lines.



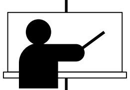
1. On your coloured triangles in Task 1, let's find all major angles and write each on the tessellation.
2. Can you find the same angles?
3. Can you find the congruent triangles?

Task 9C

Let's tessellate by only using a number of the following two shapes:



> And then, pose questions to your friends.



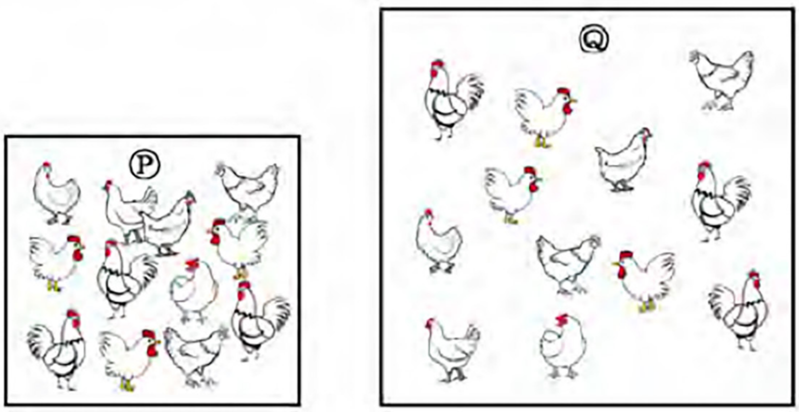
Let's explain the learning objective of these activities by using the following words:
- Tessellation is the activity to inquire plane figure by using congruent shapes as follows.
- Students find the line as for the extension of side.
- Students find the parallel line by using angle correspondence.
- Students enjoy questioning each other on the tessellation and appreciate their findings without instruction from teacher.

2.8 Chicken Farms

Task 8A

We would like to compare how chicken farms are crowded.
There are two chicken farms called P and Q.

- For comparison, what shall we do?



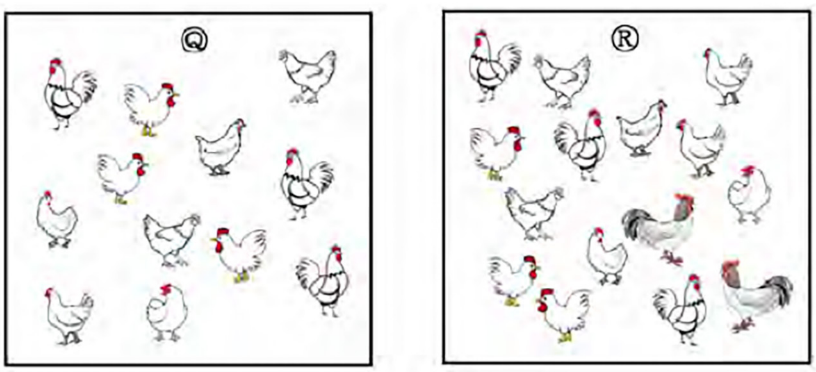
Source: Maths_Challenges_Classroom_Practices_Upper_Primary_Level, page 144 (measurement and relation)

- Mary counts the numbers of chicken in P and Q.
- Hamid orders the areas of P and Q by majoring the scale.

How shall Mary and Hamid collaborate to explain which one is more crowded by using their data?

Task 8B

How about the case of chicken farms called Q and R?



Source: Maths_Challenges_Classroom_Practices_Upper_Primary_Level, page 144 (measurement and relation)

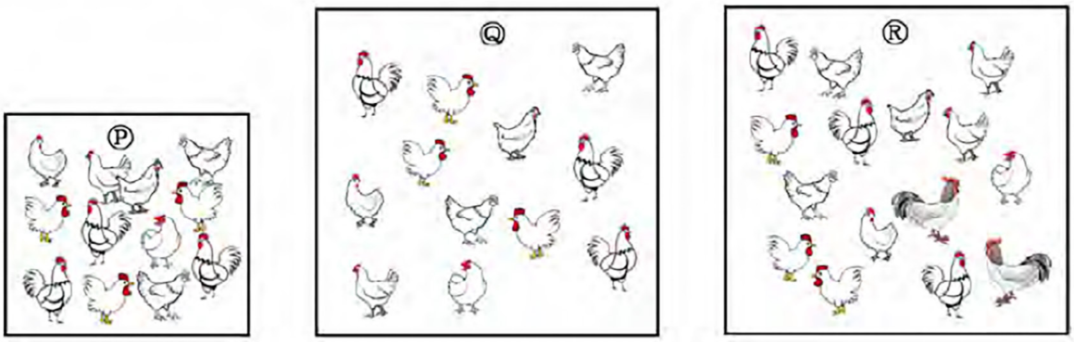
? If the number of chickens is the same, what shall we use to compare?

? If the area of farms is the same, what shall we use to compare?

Task 8C

For comparing the crowdedness for three farms, how shall they do?

- How many ways do you find?
- Which one is useful?



Source: Maths_Challenges_Classroom_Practices_Upper_Primary_Level, page 144 (measurement and relation)

Task 8D

Let's add one more chicken farm called U by yourself using the right farm-field and setting the number of chickens. And pose questions to your friends in order of the crowdedness of four farms.

U

? To make the number of chickens the same, what should we do?

? To make the area of farms the same, what should we do?

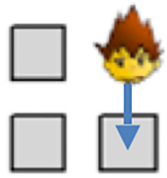
Let's explain the learning objective of these activities by using the following words:

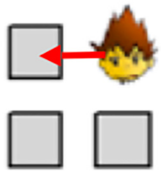
- How to produce the unit for measurement for comparison.
- For comparison of two objects, we have to compare on the same base such as on the same number of chicken or on the same area of farms.
- For comparison of more than three objects, we have to use division for getting the rate on the base unit. Depending on which one is devisor as the selected base unit, the order changes as ascending order or descending order on the ratio.
- Appreciate others' ideas for selecting the base unit for ordering and critique each other for setting the best way.

2.9 Route Finding

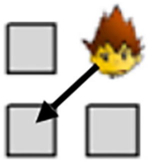
Task 4A

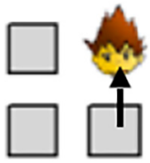
- Romy can only jump to the nearest tiles below (blue line) or to the left (red line) and both of them are called 'one step'.





- He is not allowed to jump crosswise (black line) and back to the previous position (black lines).





- On the tiles on the right, he would like to get one gold medal.
  - How many possible routes does he have?
  - How do you explain it to your friends through the telephone?
  - How many steps does he need?

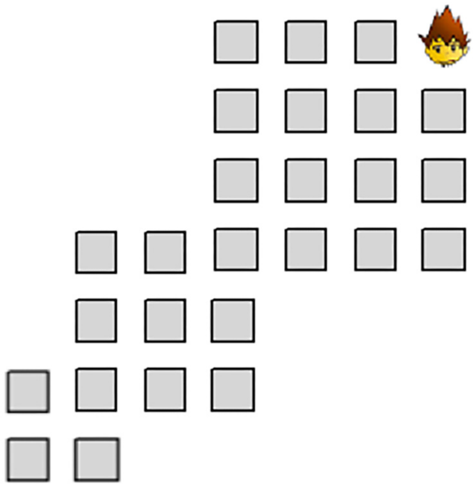
- In the case of the right tiles,
  - How many routes does he have and how many steps does he need to get a gold medal?
  - How do you explain it to your friends by using telephone?

? How can we represent the route? By using trajectory, by using the words, or by using colour.

? What do you count? By using the number of steps or by using the number of routes.

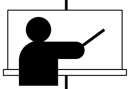
Task 4B

- Let's pose the questions to your friends by using the right tiles.



Task 4C

- Let's create your own game boards by setting the rules by yourself and enjoy it with your friends.



Let's explain the learning objective of these activities by using the following words:
- Explain the route by using the given rules through changing representations.
- Generalisation, specialisation, and inductive reasoning to find the pattern.
- Mathematisation for addition and multiplication: Finding algorism, what if and what if not for creating something new.

On Ladder Lottery, at the beginning, the roots which reach to the results are usually hidden.

2.10 Ladder Lottery   Task 10A

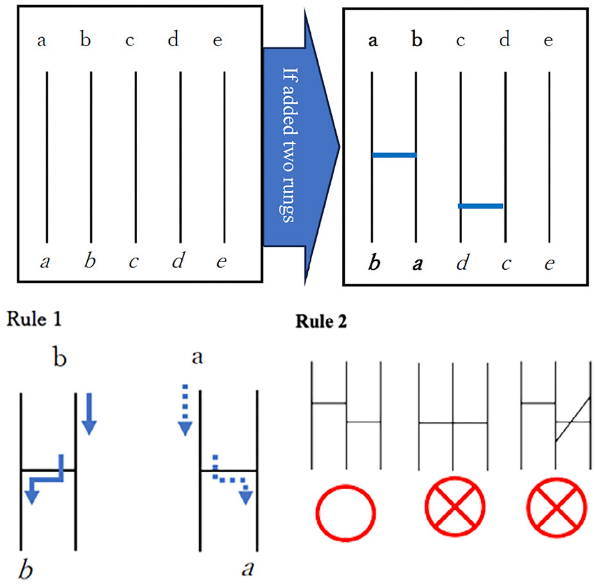
Inspired by the class of Takao Seiyama (Elementary School, University of Tsukuba)

Ladder Lottery: 'Amida Kuji' in Japanese. 'Amida' means 'Netting and Budda' and 'Kuji' means Lottery

Rule of Ladder Lottery:
There are given strings like in the right.

It shows a route as a ladder from top places to bottom places each. To reach the different place from the top to the bottom, we add the ladder rungs.

For the Lottery, ladder rungs part are hided, or participants can add any rungs under the rules:



Rule 1: We can add ladder rungs between naiver strings for changing routes. For example, when we add a rung like a right figure, we follow the rung between strings like arrows and then it exchanges the bottom place.

Rule 2: We cannot add the rung beyond naiver strings or which close another rung.

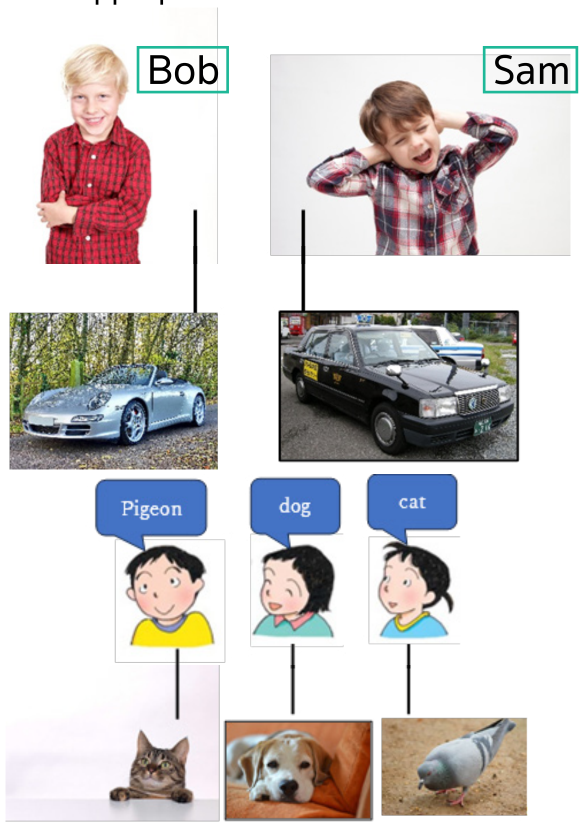
People chose the top end at first, and then, opened the roots. If the roots are uncomfortable, they can add the rungs for changing the roots to reach appropriate ends.

Task 1. Let's change the Ladder.
Bob and Sam would like to get the Sports Car. After opening the roots, Sam planned to add ladder rungs to get Sports car.

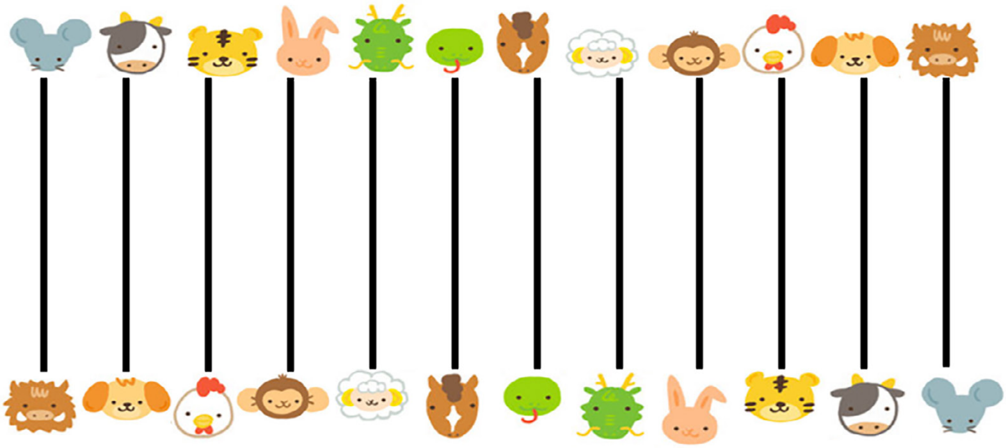
Q1. What is Sam's plan?
Q2. If Sam added rugs how shall Bob plan?

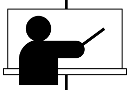
Task 2 Let's change the order.
How shall we add the rungs for each of then get what they want?

Task 3. Let's develop further ladder lottery and pose questions to your friends!



Task 4. What shall we do?





Let's explain the learning objective of these activities by using the following words:
- Inductive Reasoning and Analogical Reasoning
- Use what we found/learned at previous task for the next step
- Beautifulness of Simple Pattern and algorithm
- If we change the rules (what if not), what will happen?

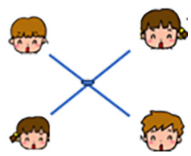
2.11 Yarn-Phone Network

Task 11A

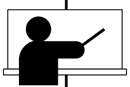
Task 1. Let's develop the Yarn-Phone Network among children by the following rules!

Rule 1. A yarn-phone connects only two children.
Q1 When there are three children, how many yarn phones do we need?

Rule 2. We cannot develop a new connected yarn phone by a knot like the right figure because it connects many children at once. We have to connect two children independently.
Q2 How many-yarn phones do we need to connect four children?

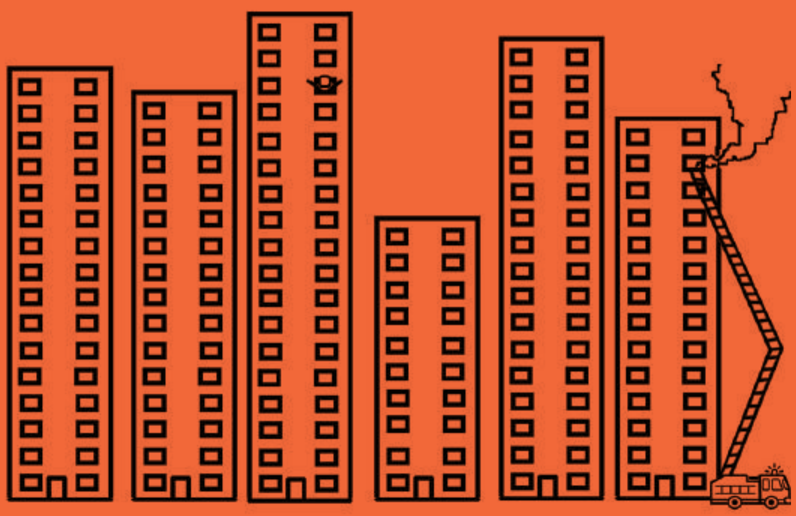


Task 2. Let's pose the questions for Yarn-Phone Network to your friends by using these rules.



This page, 2.11, is recommended to use after 2.10.
Let's explain the learning objective of these activities by using the following words:
- In Mathematics, Generalization is the nature.
- Through the finding the same algorithm/pattern/invariant structure in different situations, it become stronger.
- Appreciate the power of ordered concreate representations to find patterns.

CHAPTER 3



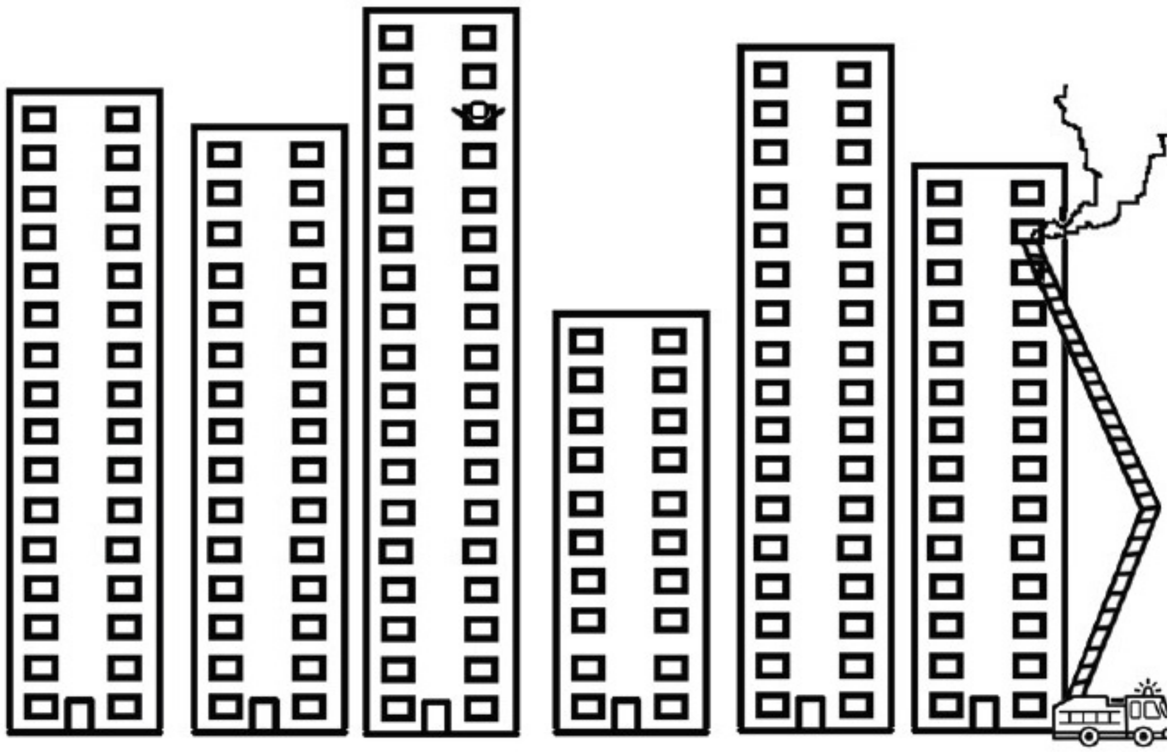
In STEM Classroom

3.1 Fire Emergency

Task 1A

Painting an apartment

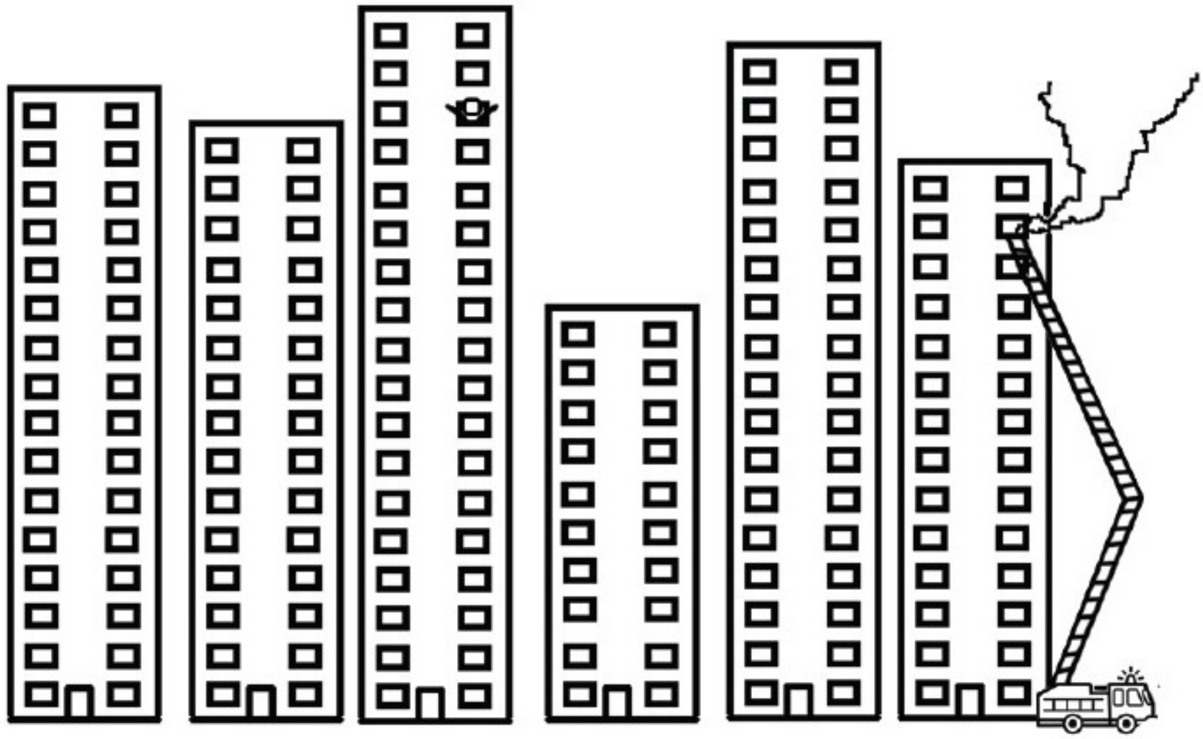
The ladder reaches exactly where the smokes come out. It does not reach higher. Paint red all the windows that are at least on the floor higher than the one with the window where the smoke comes out.



1. Let’s paint the windows based on the given condition.
2. Let’s discuss the term 'at least'.
3. Let’s explain the meaning of 'at least on the floor higher than the one with the window the smoke comes out'.

Task 1B

Calling from firefighters



The firefighters want to call each apartment in the 6 buildings. Each window is an apartment. Explain in your own words how to calculate how many apartments you have to call.

1. Let's find out by yourself on a newly given condition.
2. Let's share your achievement with others.

- ? On design. Let's think about how beautiful meant on your unique painting
- ? Reconsider the order of painting for appropriate explanation and if others drew a different picture reconsider the way to explain.
- ? Feeling of beautifulness and simpleness depends on a person. It is unnecessary that all of you will select one picture. Discuss meaning of beautifulness and simpleness in relation to the explanation on item 2 above.

A basic STEM project can be derived from this 'Calling for Firefighter'. Teachers can prepare fire extinguisher foam to be added to this mathematical thinking activity.

Task 1C

STEM Classroom Activities

It can be instructive and entertaining to make a foam STEM (Science, Technology, Engineering, and Mathematics) project about battling fires. Examining the science underlying the operation of fire extinguisher foam is one engaging exercise. Here's a basic STEM project you can do with foam:

TITLE: 'FOAM FIRE EXTINGUISHER SCIENCE'

Objective:

To comprehend the science underlying a foam fire extinguisher and how it's used in firefighting.

Materials needed for this activity:

1. Dish soap
2. Water
3. Small plastic container or bowl
4. Straw
5. Baking soda
6. Vinegar
7. Tray or shallow container
8. Tea light candle (with adult supervision)

Procedures:

Step 1 - SET UP

- The tea light candle should be placed in the middle of the tray.
- Pour water into the tiny plastic container.
- To make a soapy solution, add a few drops of dish soap to the water and stir.

Step 2 - FORMATION OF FOAM

- To make the foam, introduce air into the soapy water using a straw or pipette, and then discuss the similarities between this foam and the foam found in fire extinguishers.
- Describe how the foam is created using a combination of soap, water, and air, just like the firefighting foam that is utilised by firemen.

Step 3 - COMPREHENDING SCIENCE

- Talk about the science of foam creation. Bubbles are formed in the soapy water when air is trapped, resulting in foam.
- Compare this foam to the foam used in firefighting, which is intended to smother a fire by encasing it in bubbles and severing its oxygen supply.

Step 4 - FIRE EXTINGUISHING SIMULATION

- Sprinkle a small amount of baking soda around the tea light candle to represent a fire.
- Pour vinegar onto the baking soda to simulate the chemical reaction that produces Carbon Dioxide.
- Observe how the foam (representing a fire extinguishing agent) interacts with the 'fire' and discuss the chemical reactions occurring.

Task 1C

Questions for discussion:

- Why does the foam aid in putting out the 'fire'?
- What similarities and differences exist between the foam and the foam used in actual firefighting?
- What part do the water, air, and soap play in making the foam?

Extensions:

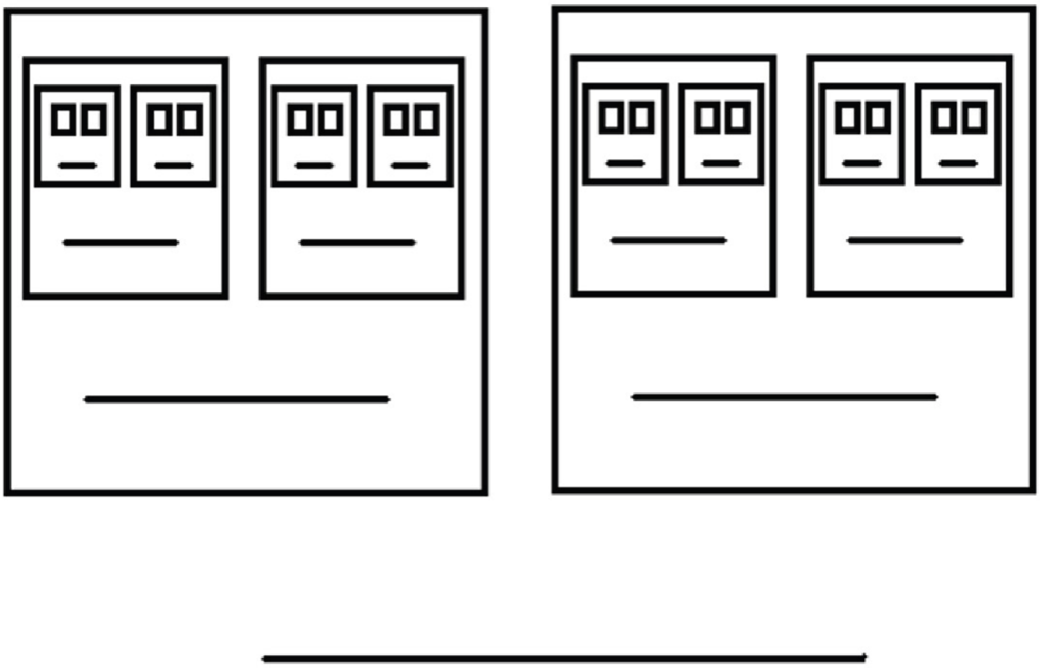
? Examine the effects of varying soap to water ratios on foam stability.

? Investigate and talk about alternative firefighting techniques and equipment.

3.2 Many Faces

Task 2A

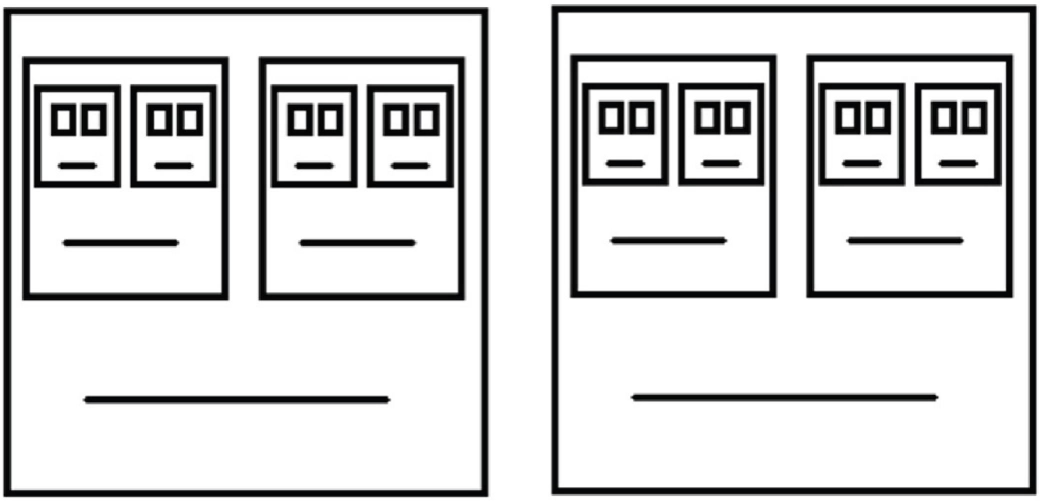
Paint Red all the smallest possible faces that contain two faces.



Source: Colouring Book [Book 2, Pages 2A]

1. Let's paint the faces based on the given condition.
2. Let's discuss the term 'smallest possible'.

Task 2B



Source: Colouring Book [Book 2, Pages 2B]

1. Let's create commands to design a beautiful painting by using number '2' in the commands.
2. Discuss with your friends how you see and paint each 2 faces.

Create an art project where students use the number '2' as a design element. They can draw two of something or arrange objects in groups of two.

Story Building:
Have students create a short story where the number '2' plays a significant role. For example, 'There were 2 friends who went on 2 adventures.'

Task 2C

Activities related to STEM (Science, Technology, Engineering, and Mathematics) can be combined to create a more comprehensive educational experience.

1. Art with 2s (STEM Integration):

Science: Study symmetry in nature and art in science.
Technology: Create and manipulate art using digital technologies.
Engineering: Create a project that integrates structural and artistic aspects.
Mathematics: Incorporate geometric and symmetrical ideas from mathematics into the artwork.

2. Word Problems (STEM Integration):

Science: Construct word puzzles that highlight scientific topics while promoting analytical thinking and problem-solving skills.
Technology: Tackle word problems with dynamic circumstances, use online simulations.
Engineering: Present engineering difficulties as word puzzles to stimulate original problem-solving.
Mathematics: Convert situations from the real world into mathematical statements and equations.

By adding STEM components to these exercises, you may improve the learning process by offering a more practical and multidisciplinary approach. Because STEM integration fosters creativity, critical thinking, and problem-solving skills. Also, it improves student engagement and makes learning more applicable to real-world situations.

Note:

3.3 Preparing a Breakfast

Task 3A

Grouping

Worksheet

A Bowl of Cereal	A Cup of Cocoa

Put Cereal into a Cup	Open a Cereal Box	Add Cocoa Powder	Add Milk	Boil Water	Add Sugar	Add Milk	Put Hot Water into a Cup	Stir Thoroughly

Source: Code.org Real-life Algorithm

You are preparing a bowl of cereal and a cup of cocoa for your breakfast.

1. Cut out the steps in the small boxes and identify which steps are for making a bowl of cereal and which steps are for making a cup of cocoa.
2. Put the steps into a correct box below the name of the food.
3. Identify the sequence of the step and sort them into a proper order.

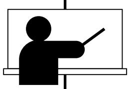
Questions to help student exercise their critical thinking skill.
What will happen if we do the step in a different order?

< back to contents

Task 3B

Think about different tasks that you need to do after waking up.
1. Breakdown each task to smaller steps. Write down those steps into a sequence.
2. Share this sequence to your friend and let them act as if they are performing these tasks.
3. See if they can perform all the tasks correctly.

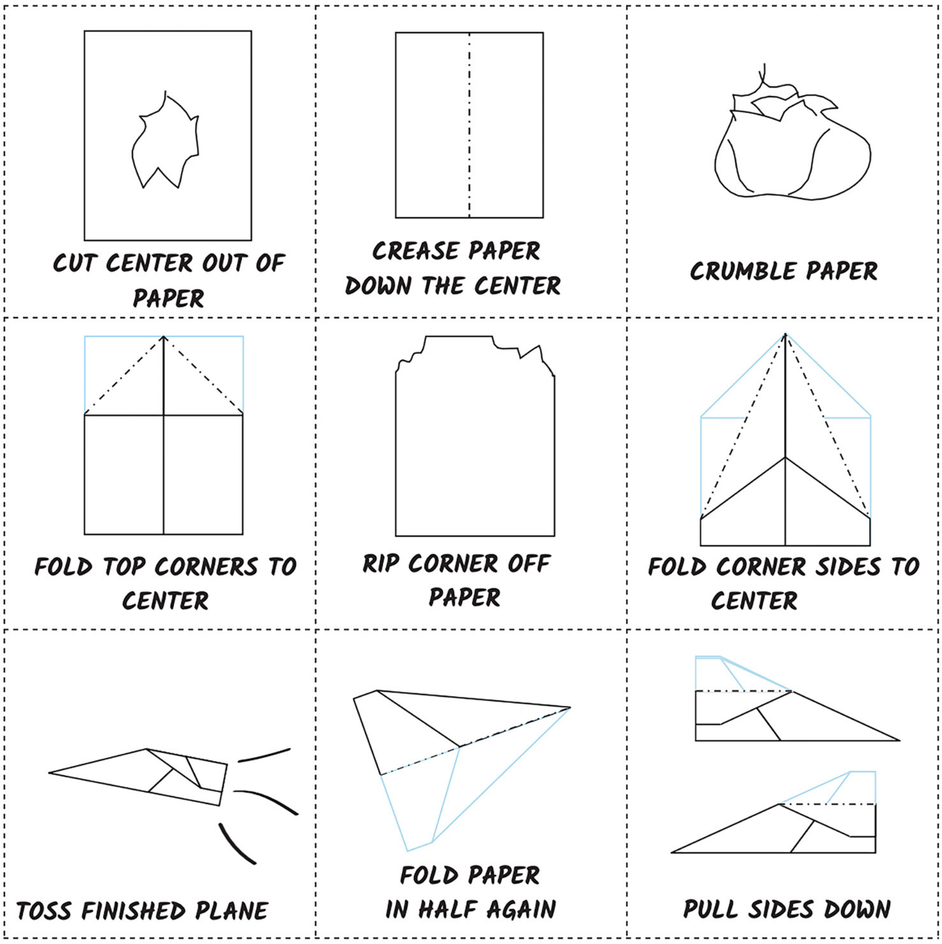
Discussion Questions:
1. Why do we need to do the task in this particular sequence?
2. What will happen if your friend performs the task in a different order?
3. Which steps can be skipped?
4. What will happen when some steps are skipped?



To help the student exercise their decomposition skill:
- Ask whether a particular step can be performed differently. If so, could that step be decomposed further into smaller steps to ensure that the task will be performed exactly as planned.

Let's explain the objectives of these activities using the following words:
Algorithm, Decomposition, and Order.

3.4 Paper Plane — Task 4A



Source: Code.org Real-life Algorithm

Instruction for Students:

1. Make a copy of the worksheet above. Cut out the steps of making an airplane.
2. Glue the six correct steps, in order, onto a separate piece of paper.
3. Make an actual paper plane following these steps.

Questions to help student exercise their critical thinking skill.

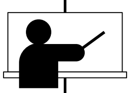
- What would you have added to make the algorithm even better?
- What if the algorithm had been only one step: 'Fold a Paper Plane'? Would it have been easier or harder?

< back to contents

Task 4B

1. Have another student fold other types of airplanes, without other students seeing how the plane is folded.
2. Show the finished paper plane to other students.
3. Unfold the folded plane back into a single page.
4. Let other students try to fold the paper into the airplane again by observing the folded line on the paper.
5. Let the student discuss how they think.

Discussion Questions:
1. Why do we need to develop an algorithm?
2. If the paper is in different size, or different orientation, is there another step needed?
3. Which step, if failed to implement properly, will make a plane have difficulty flying?
4. Discuss what would happen if you skip the step before the next one.



To help the student exercise their algorithmic thinking capability:
Let the student think about other activities in their daily life and develop an algorithm to accomplish those tasks.

Let's explain the objectives of this activities using the following words:
Algorithm, Symmetry, and Pattern.

This worksheet is adapted from a learning material from Code.org.

3.5 Pattern Recognition

Task 5A

Identify Common Elements

Worksheet (a)

Note: All images have been developed using ChatGPT.

Instruction for Students:

1. Identify elements that make you recognise the animal in these pictures as elephants. List down those elements.
2. Identify behaviour of the elephants, what do they usually do.

Questions to help student exercise their critical thinking skill.
Without visually seeing the elephant, if different students are touching different parts of an elephant, how will they describe an elephant.

< back to contents

Task 5B

Identify Common Elements

Worksheet (b)






Note: All images have been developed using ChatGPT.

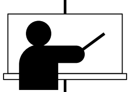
Instructions for Students:

1. Share the list of elements of an elephant to your friends.
2. In each picture, make a checklist of elements that each picture contains.
3. Identify from the checklist, whether the animal in the picture is an elephant or not.

Discussion Questions:

How can we recognise an elephant even without seeing all the elements we listed down for an elephant? What is the most important element which can be used to distinguish elephants from other animals?

Why do we recognise that a particular animal is not an elephant even though they have all the elements in the list?



Questions to help student exercise their critical thinking skill.
How can we recognise people and identify which part of the world or which countries they came from?

Let's explain the objectives of this activity by using the following words:
Algorithm, and Pattern.

3.6: Image Recognition Task 6A

Image Recognition with Cats, Cars, Houses

Worksheet



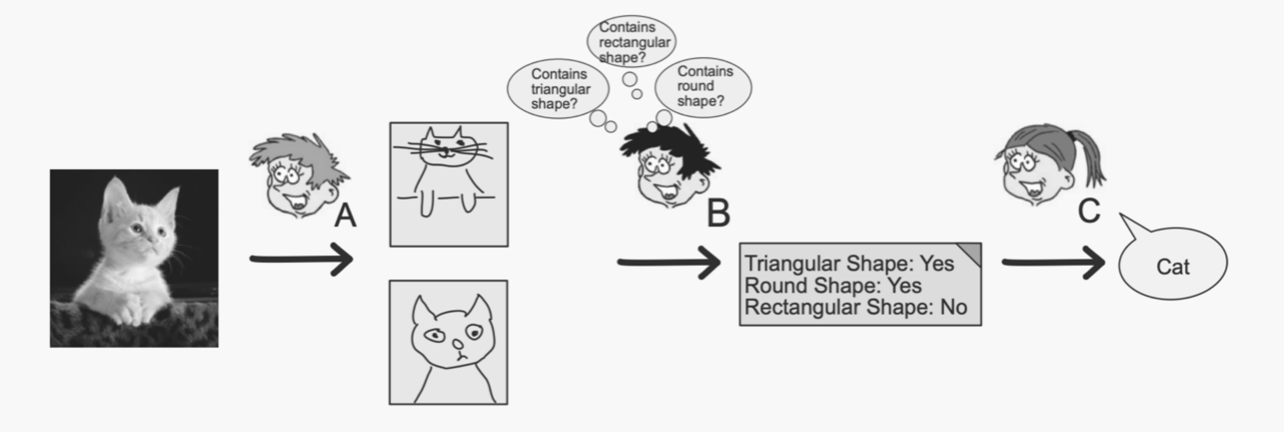





Note: All images have been developed using ChatGPT.

Instruction for Students:

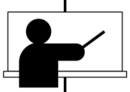
1. Divide students into three groups. Each group performs one of the three rolls, each representing one layer of a neural network. The tasks of the three roles are as follows:



- **Group A:** Looks at the images from the worksheet (B and C should not see the image!), creates a simplified sketch of each image and passes them on to B. It is important that C does not see the sketches.
- **Group B:** Receives the sketches from A and checks whether square shapes, triangular shapes or round shapes are included. Write down the number of each shape. Then, passes the information on to C.
- **Group C:** Evaluates the information received using the following table and announces whether the original picture is a house, a car or a cat.

	Rectangular shape?	**Triangular shape?**	**Round shape?**
House	Yes	Yes	No
Car	Yes	No	Yes
Cat	No	Yes	Yes

2. A determines whether the solution is correct.

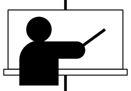


Questions to help student exercise their critical thinking skill.
What will the students do if you hand out some images to the students that do not fit into the categories identified by the decision table?
For instance, an image that consists of three types of shape.

Task 6B

1. Find a set of different pictures such as dogs or fans. Let the student discuss how to develop a decision tree to recognise objects in those pictures.
2. Try out another round of image evaluation process in item 1. This time let Group C uses the newly developed decision table.

Discussion Questions:
How can we improve the decision process to ensure that the categorisation process will always be correct with more sophisticated pictures?



Questions to help student exercise their critical thinking skill.
How can students recognise their friends after seeing their faces?
What elements in those faces can help distinguish one individual from the others?

Let's explain the objectives of this activity by using the following words:
Algorithm, and Pattern.

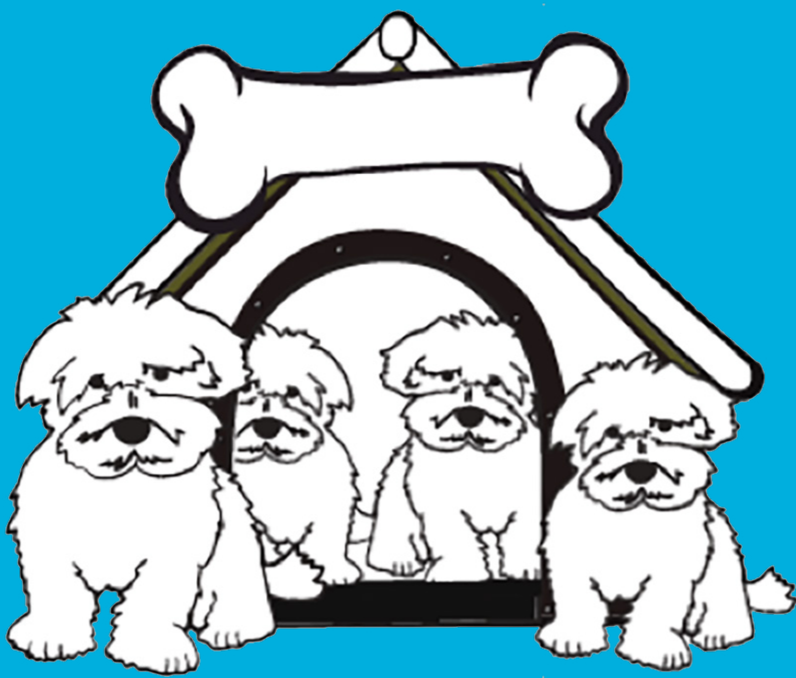
This learning unit is adapted from the work developed by:
Annabel Lindner, Stefan Seegerer
Professorship for Computer Science Education Friedrich- Alexander- Universität Erlangen- Nürnberg Martensstraße 3
91058 Erlangen
https://aiunplugged.org

Note:

CHAPTER

4

< back to contents



Visible Programming

Visual Programming for Computational Thinking

Visual programming and computational thinking (CT) are closely related concepts. Visual programming involves using graphical elements to create computer programmes, while computational thinking refers to the problem-solving and analytical skills used in computer science and programming. Visual programming environments often encourage the development of computational thinking skills by providing intuitive interfaces and visual representations of programming concepts. Through visual programming, users can practise decomposition (breaking down problems into smaller parts), pattern recognition (identifying similarities between different programming tasks), abstraction (creating general solutions to specific problems), and algorithm design (developing step-by-step procedures to solve problems).

In summary, visual programming and computational thinking are intertwined, with visual programming serving as a practical tool for fostering and applying computational thinking skill in the context of programming and problem-solving.

** Scratch – Visual programming used in this chapter*

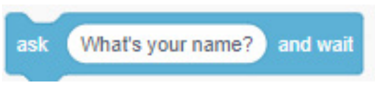
Visual programming for computational thinking, exemplified in platforms like Scratch, utilises graphical elements to facilitate the creation of computer programmes. In the Scratch ecosystem, users employ a drag-and-drop interface to assemble colourful blocks representing various programming constructs such as loops, conditions, and events. This approach abstracts traditional code into visual components, making coding more intuitive and accessible, particularly for learners with little to no programming experience. By visually arranging these blocks, users can design interactive stories, games, and animations, fostering creativity and problem-solving skills while simultaneously honing their computational thinking abilities.

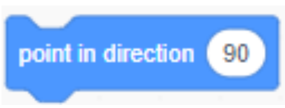
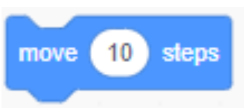
4.1 Let's Use Arrow Keys to Move the Sprite

Preparation:
From the task sequence, let's make clear the objective of your lesson by yourself:
- Guess the functions of each command for a Sprite through analysis of a given programme.
- Find the meaning of sequence commands through the running of the programme.
- Utilise what is learned for further challenges.

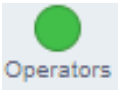
< back to contents

No	Block Programming	Function
1		This command is used to create a loop that repeats its contained code indefinitely. It's commonly used for actions that need to continuously occur, such as updating the position of a sprite or checking for certain conditions.
2		This command is a conditional statement. It checks a specified condition and executes the contained code block if the condition is true.
3		This is an extension of the If-then command. It allows you to specify an alternative code block to execute if the condition is false.

No	Block Programming	Function
1		This command checks whether a specific key on the keyboard is currently being pressed. It's often used in games to trigger actions when certain keys are pressed.
2		This command prompts the user with a message and waits for them to input text. It's commonly used to gather input from the user during a programme's execution.

No	Block Programming	Function
1		This command changes the direction that a sprite is facing. You can specify a direction in degrees, with 0 being to the right, 90 being up, 180 being left, and 270 being down.
2		This command moves a sprite a specified number of steps in its current direction.

No	Block Programming	Function
1	say (Hello!) for (2) seconds	This command displays a message from a sprite for a specified duration of time.

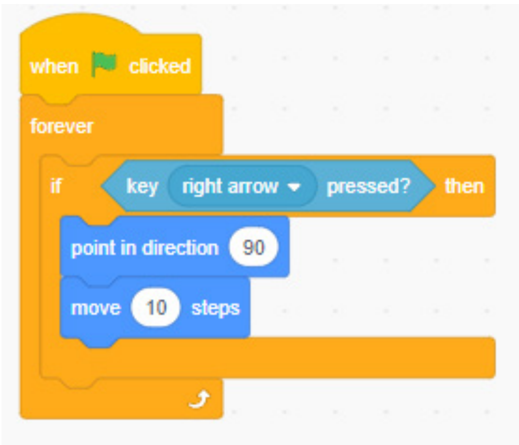


No	Block Programming	Function
1	( ) > (50) ( ) < (50) ( ) = (50)	These are comparison operators used to compare two values. '>' means greater than, '<' means less than, and '=' means equal to.

Task 1A

A simple programme related move directions are given as shown below:

Let's try to guess the meaning of the script structure by using the given



- Before running the programme, look at the programme script and guess how the Sprite moves. And then discuss your hypothesis with your friends.
- After discussions, let's run the programme and confirm how the Sprite moved. Is it the same as your expectation?
- For further knowing the commands, change the parameter and sequence of commands.

Let's discuss your expectations first and then run for confirmation.

< back to contents

Task 1B

Let's pose questions to your friends in relation to setting parameters like the following and check it.

'I would like the hens facing to the left and moving 20 steps when I press the left arrow on the keyboard. How shall I use code commands and set parameters?'

Your Questions:

Notes: Describe what happen to your Sprite based on your first block programme

Task 1C

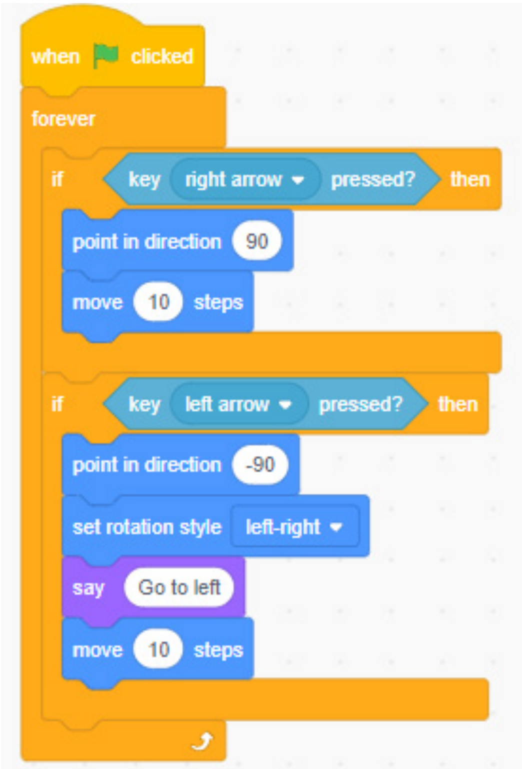
Using what you learned on task 1 and 2, let's plan the further motion of the Sprite by yourself like a sample. And then, write the programme for yourself.

Sample: 'Adding new function for arrow up and down on keyboard, Sprite facing up and down, and play sound Meow each time direction changed.'

Your Planned Motion:

Notes: Describe what happen to your Sprite based on your first block programmes

? In case, the motion of your programme is not the same as your expectation, how shall you do? If you succeed, please demonstrate it to the others by asking questions about the motion of Sprite such as 'OK, can you guess the programme of this motion?'

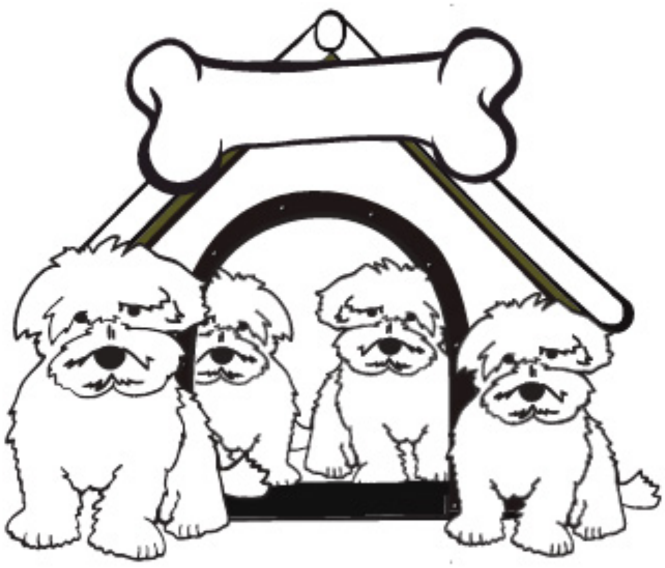


Example:
Roy wrote the programme for the sample.

When the left arrow on the keyboard is pressed, Sprite facing left and move 10 steps, and show the message 'Go to left', else when arrow key pressed right, Sprite facing to the right and move 10 steps without showing the message.

Does it work as expected?

4.2 Let's Using Variables and Loop Functions

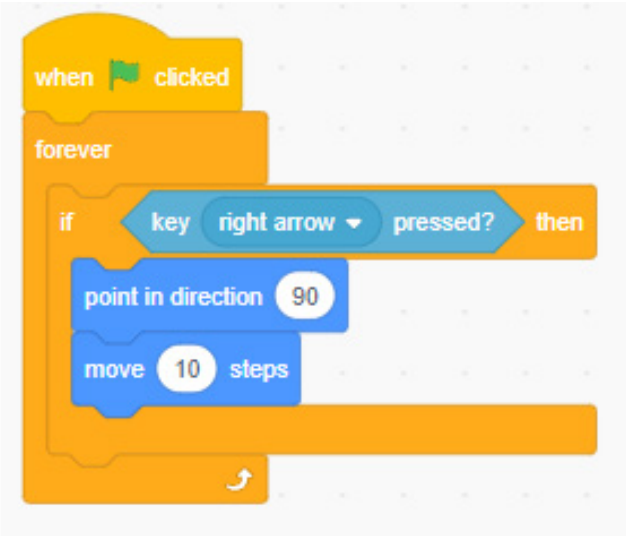


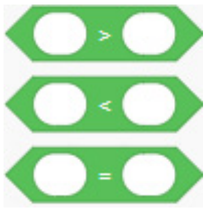
Source: Colouring Book [Book 1, Page 8A]

Preparation:
From task sequence, let's make clear the objective of your lesson by yourself:
- Guess the functions of each command for a Sprite through analysis of a given programme.
- Find the meaning of sequence commands through the running of the programme.
- Utilise what is learned for further challenges.

Task 2A

Let's explore the functions of commands for Sprite from the given programme through changing the parameters on the commands. On the exploration, let's discuss the appropriate function of each command.



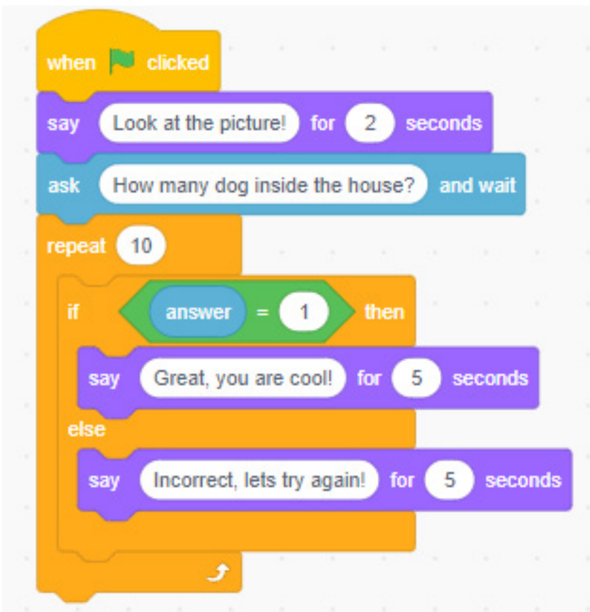
Command	Function
	
	
	
	

Task 2B

Add a loop command so the programme will run until the correct answer is inputted. Discuss it with others. Then, check it!

<table>
<tr>
<td>

For example,

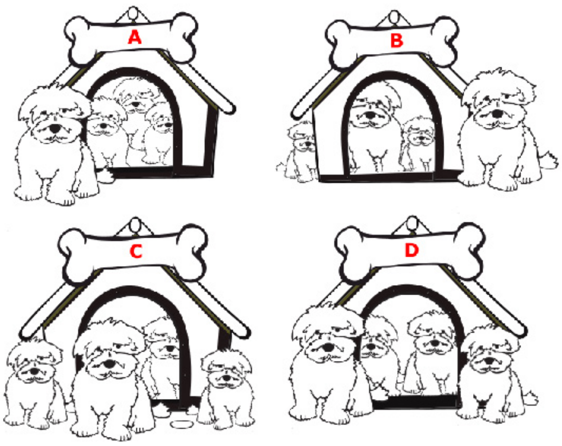


</td>
<td>If you add a repeat command, what will happen?</td>
</tr>
</table>

< back to contents

Task 2C

Let's explore the Scratch environment by changing the Stage backdrops.

	How to loop four times with changing the Stage backdrops and questions!

Your Changed Backdrop 1:

Guessing and Discussing:

Checking:

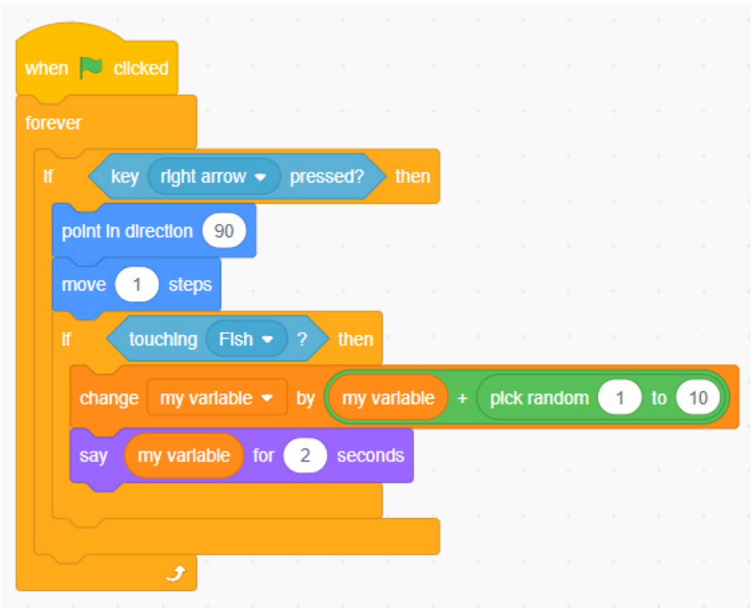
Your Changed Backdrop 2:

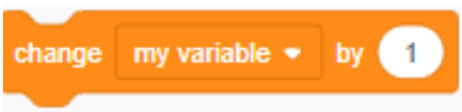
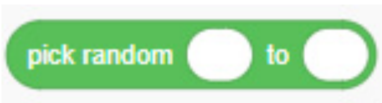
Guessing and Discussing:

Checking:

Task 2D

Let's explore the functions of commands for Sprite from the given programme by adding the commands below. On the exploration, let's discuss the function of each command.



Command	Function
	
	
	

Explaining the process steps and predicting the output of the block code above!

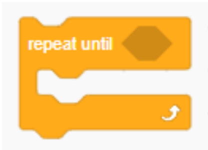
Your Questions:

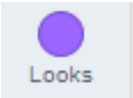
4.3 Meet the Maximum Value

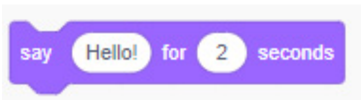
The following is an explanation of major commands to use in Scratch.

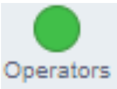
Category	Command	Function
Looks	Say ()	Displays a message or text bubble by the sprite.
Control	When Green Flag Clicked	Starts the script when the green flag icon is clicked.
	If () Then	Allows conditional execution of code based on a condition.
	Repeat until ()	Loops a set of commands from the first number of times until the last number of times.
Operators	() + ()	Add two numbers together.
	() = ()	Check if two value are equal
	() < ()	Checks if one value is less than another.
Variable	Set variable to ()	Determine variables which were created
Make a list	New list	To create a new list.
	Add () to list	Add values in the list.

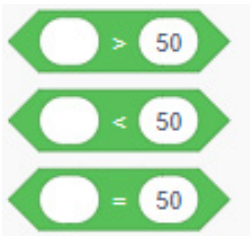
Preparation:
From the task sequence, let's make clear objectives of your lesson by yourself:
- Set the value of variables.
- Create a list.
- Add values in a created list.
- Write scripts to find out all of eight values which one is the maximum value.

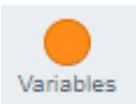
No	Block Programming	Function
1		This command is a conditional statement. It checks a specified condition and executes the contained code block if the condition is true.
2		This command is useful to create a loop when something needs to happen before the loop should stop. If we keep asking 'Why?' until an answer was given, then this block would be used for that.

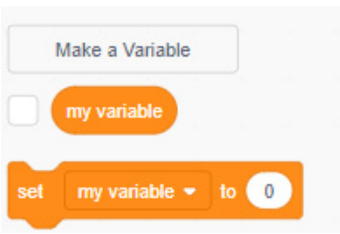
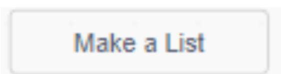


No	Block Programming	Function
1		This command displays a message from a sprite for a specified duration of time.



No	Block Programming	Function
1		These are comparison operators used for comparing two values. These symbols are '>' means greater than, '<' means less than, and '=' means equal to.



No	Block Programming	Function
1		To create a variable, a type of variable given, a name, and a value, what kind of value the variable will hold.
2		Lists are collections of data items that can be used in Scratch programming.

< back to contents

Neighbouring Cell — Task 3A

2	1	3	5	6	3	3	4	3	0
10	3	2	2	7	4	5	5	4	2
11	13	2	3	4	9	10	3	14	13
21	3	20	4	4	19	5	15	4	3
22	4	4	20	5	25	6	16	25	5
30	24	5	18	6	25	6	6	19	4
32	4	6	16	6	17	6	6	4	4
2	4	26	15	12	19	27	35	25	15
32	34	36	37	38	10	47	41	35	14
38	44	35	8	39	28	29	38	18	13
11	4	4	6	40	38	9	10	11	12
0	0	3	4	41	8	8	5	4	2

Let's consider 8 directions namely:

- move to the right,
- move to the left,
- move up,
- move down,
- move diagonal down right,
- move diagonal down left,
- move diagonal up left, and
- move diagonal up right.

A programming related setting directions are given as shown below:

Let's discuss the meaning of the script above.

- ? Before running the programme, study the programme script and guess what is going to happen on the stage view.
- ? After discussions, let's run the programme and confirm. How? Is it the same as your expectation?
- ? For further studying the setting, change the number at the centre and the neighbouring cells. Let's discuss your expectations first and then run for confirmation.

Quantity List — Task 3B

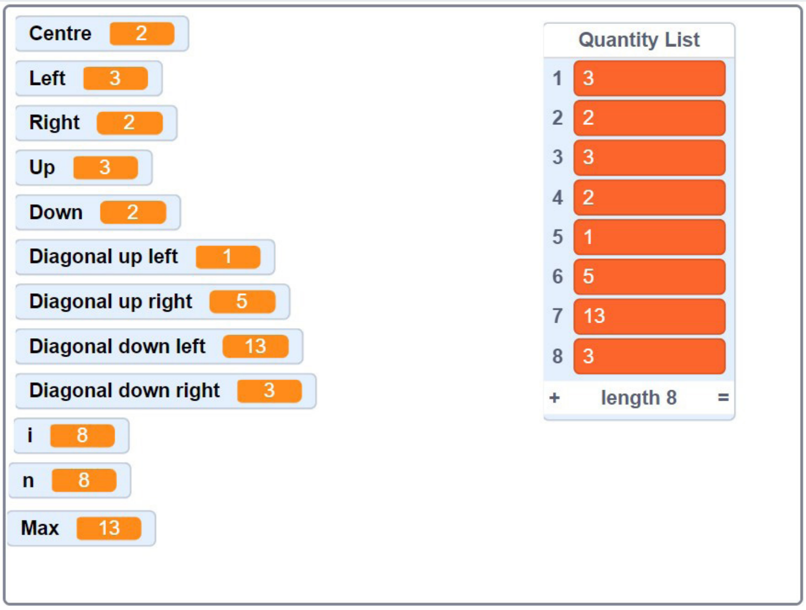
Let's create a quantity list and add the values in relation to the numbers for 8 directions in task 3A.

Let's discuss and guess what it will appear in the list.

Questions and Discussion:

Notes: Explanation what happen to your stage view on your first block programme

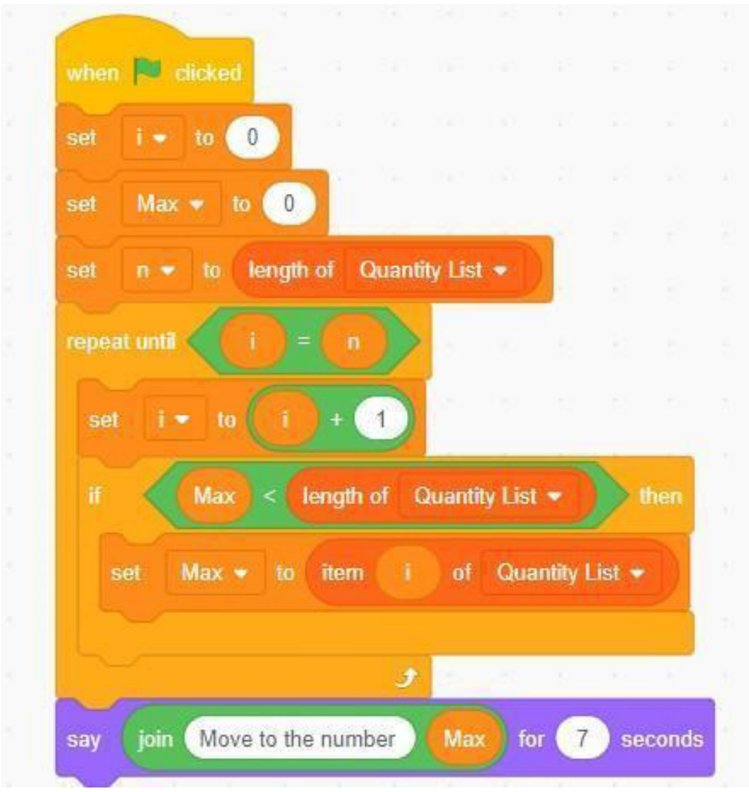
After setting the number and creating the quantity list then running the programme, the result and the quantity list will appear on the stage view below.



Let the students observe if they change the numbers at the centre and the neighboring cell.

Maximum Value Task 3C

Write scripts to find out maximum value from the quantity list as shown below:
Let's try to guess the meaning of commands and create new variables namely: i, n and Max.

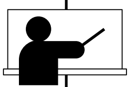


? Before running the programme, try to understand the programme script and guess the result on the stage view.

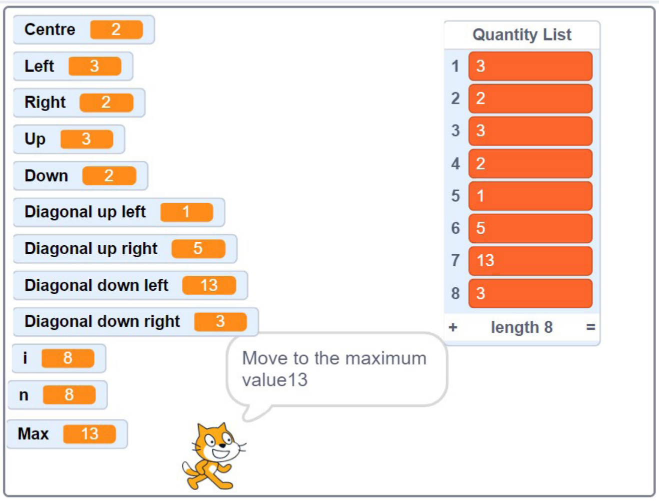
? Let's discuss and explain the meaning and relationship of variables in the command.

? After discussions, let's run the programme and confirm. How? Is it the same as your expectation?

? For further studying and running the commands, change the variables and observe what is going to happen.



After running the command and the result will appear as shown below.



Let students observe after running the command. The sprite will tell the maximum value.

Maximum Value Task 3D

Using what you have learned on task 3A, 3B and 3C, let's change the position of the central number by yourself and then write the programme for yourself. Are there any other ways of programming?

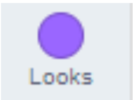
Your Programming:

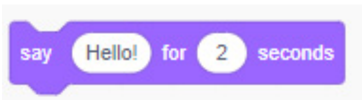
In case, your programme does not get the same as your expectation, how shall you do? If you succeed, please demonstrate it to the others by asking questions about the finding of maximum value such as 'Can you guess the programme of this finding?'

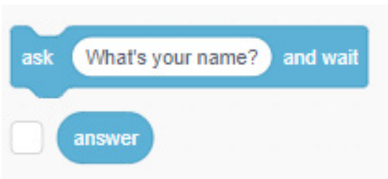
4.4 Move the Rock

Preparation:
From the task sequence, let's make clear objectives of your lesson by yourself:
- Determine the value of numerator and denominator
- Define fraction.
- Compare 2 fractions.
- Write scripts to find out whether the neighboring cell is less than the present cell.

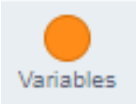
No	Block Programming	Function
1		This command is a conditional statement. It checks a specified condition and executes the contained code block if the condition is true.

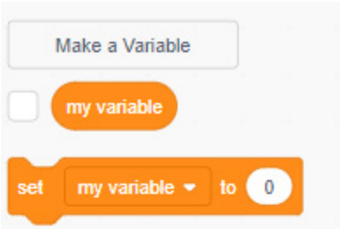


No	Block Programming	Function
1		This command displays a message from a sprite for a specified duration of time.

No	Block Programming	Function
1		As this block allows users to input any text they want, it is widely used when a user must communicate with the project.

No	Block Programming	Function
1		The operator for subtraction. These are comparison operators used for comparing two values. These symbols are '>' means greater than, '<' means less than, and '=' means equal to.



No	Block Programming	Function
1		To create a variable, a type of variable given, a name, and a value, what kind of value the variable will hold.

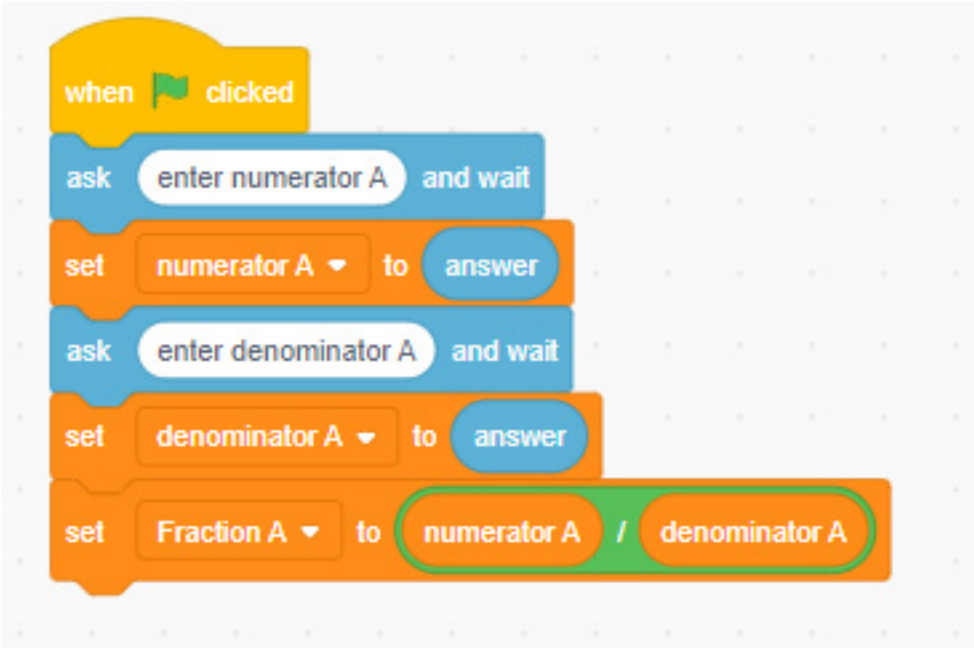
Setting Numerator and Denominator — Task 4A

Every time the rock moves to the neighboring cell that has the lowest number, but if there is not any one lower than where it is, then it stays there.

1	$\frac{3}{4}$	$\frac{3}{5}$	$\frac{2}{5}$
$\frac{2}{2}$	$\frac{4}{8}$	$\frac{2}{5}$	$\frac{2}{6}$
$\frac{1}{4}$	$\frac{1}{3}$	$\frac{2}{3}$	$\frac{1}{3}$
$\frac{1}{5}$	$\frac{2}{9}$	$\frac{3}{9}$	$\frac{1}{7}$
$\frac{3}{8}$	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{9}$

Source: Colouring Book [Book 2, Page 11 A]

A programming related setting numerator 'A' and denominator 'A' to form fraction 'A' are given as shown below:



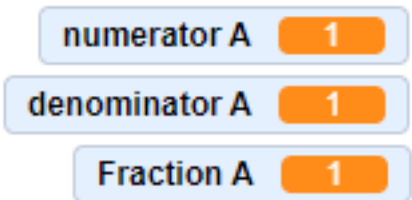
Let's discuss the meaning of the script above.

? Before running the programme, study the programme scripts and guess what it is going to happen on the stage view.

? After discussions, let's try and run the programme to confirm 'How?' and 'Is it the same as your expectation?'

? For further studying the setting, change the numerator and the denominator. Let's discuss your expectations first and then run for confirmation.

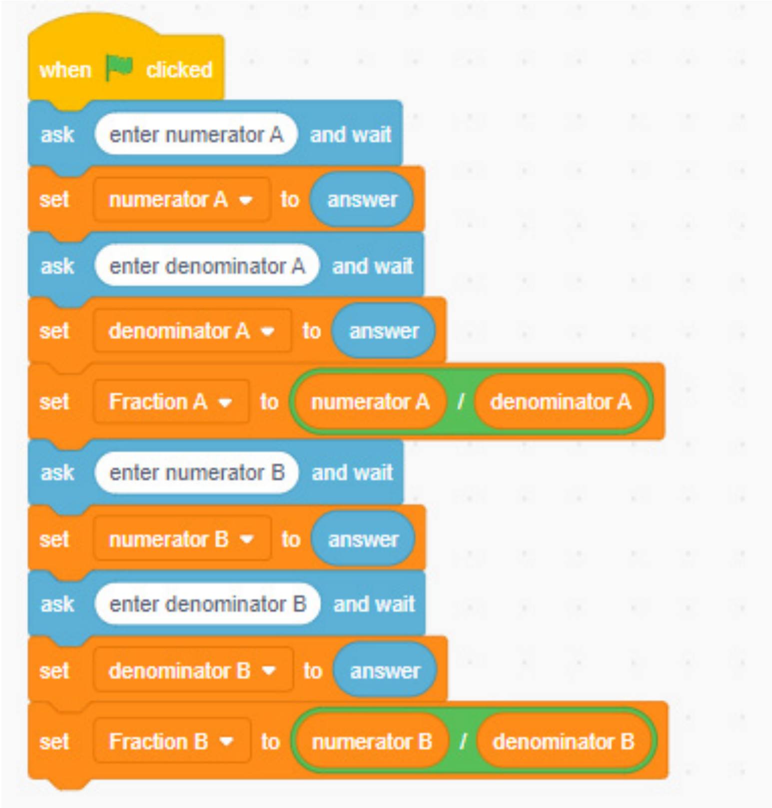
After setting the numerator and denominator then run the programme, The result below will appear on the stage view.



Let’s discuss changing the numerator and the denominator.

Setting Fractions — Task 4B

A programming related setting 2 numerators and 2 denominators to form fraction A and B are given as shown below:

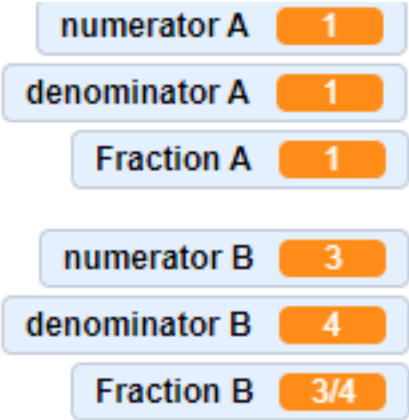


Let’s discuss and guess what will appear on the stage view.

Questions and Discussion:

Notes: Explanation what happen to your stage view on your programme

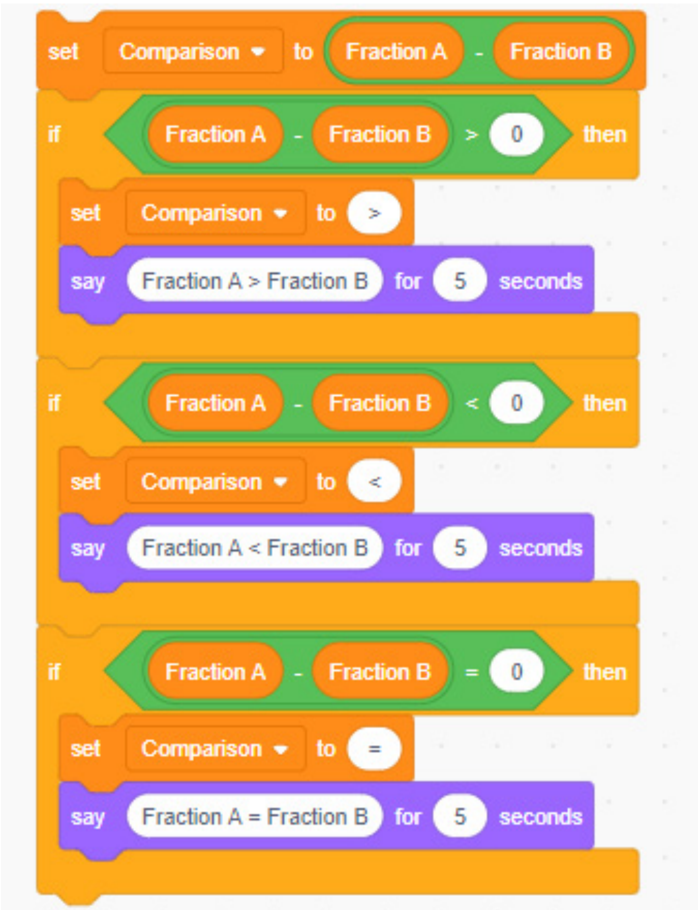
After setting the numerators and denominators then run the programme, The result will appear on the stage view below.



Let the students observe if they change the numerator and denominator. What will the result appear?

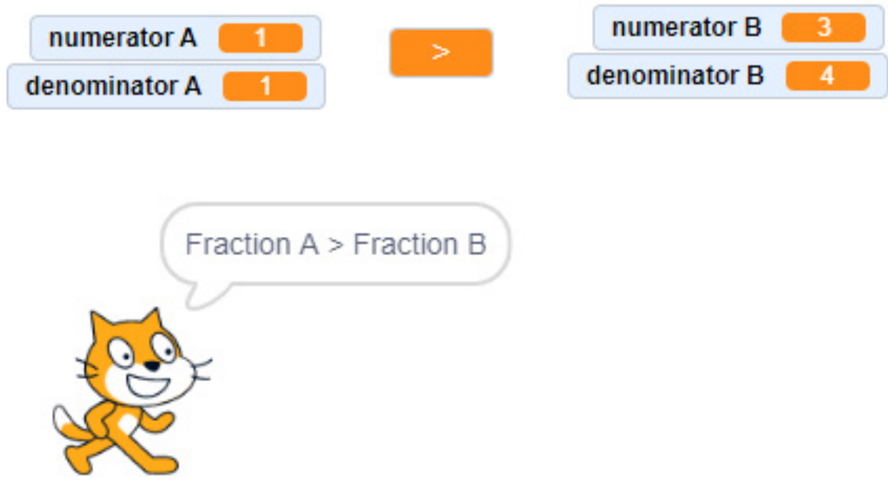
Comparing Fractions Task 4C

Write scripts for comparing fractions 1 and $\frac{3}{4}$ from task 4A and 4B as shown below.
Let's try to guess the meaning of commands and determine numerator and denominator by yourself



- ❓ Before running the programme, try to understand the programme script and guess the result on the stage view.
- ❓ Let's discuss and explain the meaning of variables in the command.
- ❓ After discussions, let's run the programme and confirm, 'How?' and 'Is it the same as your expectation?'
- ❓ For further studying and running the commands, change the numerator and denominator then observe what is going to happen.

After running the command and the result will appear as shown below.



Let students observe after running the command. The sprite will tell the result.

Write your Programming — Task 4D

Using what you have learned on task 1, 2 and 3, let's change the numerator and denominator by yourself and then write the programme for yourself. Are there any other ways to write the scripts?

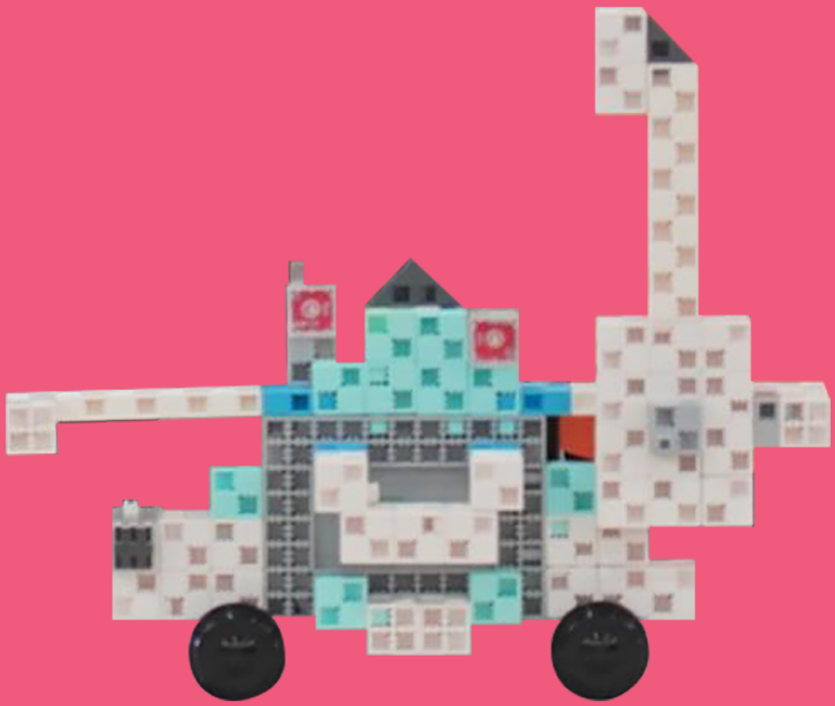
Your Programming:

In case, your programme does not get the same as your expectation, how shall you do? If you succeed, please demonstrate it to the others by asking questions about the finding of comparing fractions such as 'can you guess the programme of this finding?'

CHAPTER

5

< back to contents



Let's Develop Machine

5.1 Let's Run Robot Car Using a Motor.

Preparation:
From Task sequence, let's make clear the objective of your lesson by yourself:
- Guess the function of each command for a robot through analysis of given programme.
- Find the meaning of sequence commands through the running of programme.
- Utilise what learned for further challenges.

**Studuino is a programming environment by Scratch to control ArTeC Robo as block components. Following is a minimum explanation of major commands which we use.*

Motion

No	Block Programming	Function
1		Sets the DC Motor to the direction clockwise or counterclockwise.
2		Adjusts the DC motor's speed between 0 and 100. The DC motor will revolve more quickly when you increase the speed. Any value less than or equal to 0 will be set to 0, and any value larger than or equal to 100 will be assigned to 100.
3		Sets how the DC motor will stop (Brake or Coast)

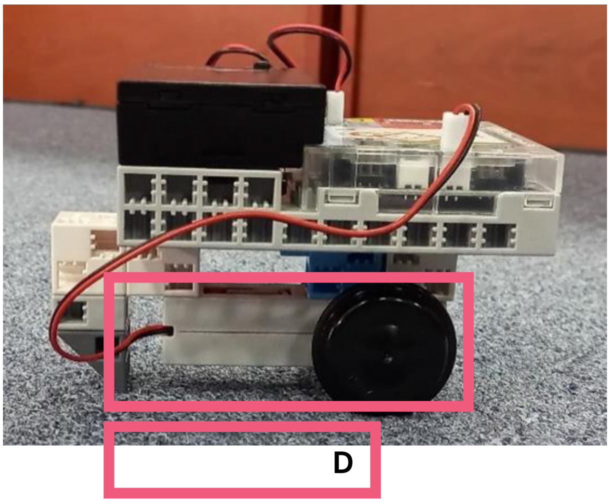
Control

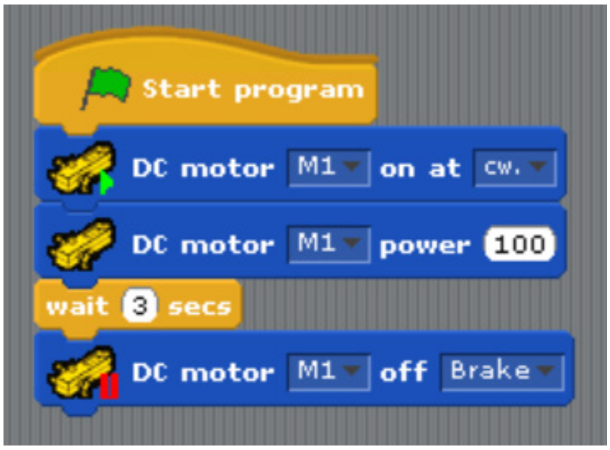
No	Block Programming	Function
1		Wait for a specific time (for example 1 second).

Limited Instruction for going to the task 1:
How to connect microcomputer and computer, and microcomputer and DC motor. How to open Studuino Software

Task 1A

A simple robot car and the programme are given as shown below:





Let's try to guess the meaning of the programme script by using the given.

- ? Before running the programme, read the programme script and guess how the robot move. And then, discuss your hypothesis with your friends.
- ? After discussion, Let’s run the programme and confirm how car moved. Is it the same as your expectation?
- ? For further knowing the commands, change the parameters and sequence of commands. let’s discuss your expectation at first and then run for confirmation.

Task 1B

Let’s pose questions to your friends in relation to setting parameters like the following and check it.
'I would like to run the car, around 30 cm long. How shall I set parameters?'

Your Questions:

Notes: Describe what happen to your robot based on your first block programmes

Task 1C

Using what you learned on Task 1A and 1B, Let's plan the further motion of the car by yourself like a sample. And then, write the programme for yourself.
Sample: 'Go forward for 3 seconds, Stop for 2 seconds, Go backward for 2 seconds, and Stop'

Your Planed Motion:

Notes: Describe what happen to your robot based on your first block programmes

❓ In case, the motion of your programme is not the same as your expectation, how shall you do?

❓ If you success, please demonstrate it to the others by questioning about the motion of Robot such as 'OK, can you guess the programme of this motion?'

Example:
Wara wrote the programme for the Sample: 'Go forward for 3 seconds, Stop for 2 seconds, Go backward for 2 seconds, and Stop'

Does it work as expectation?

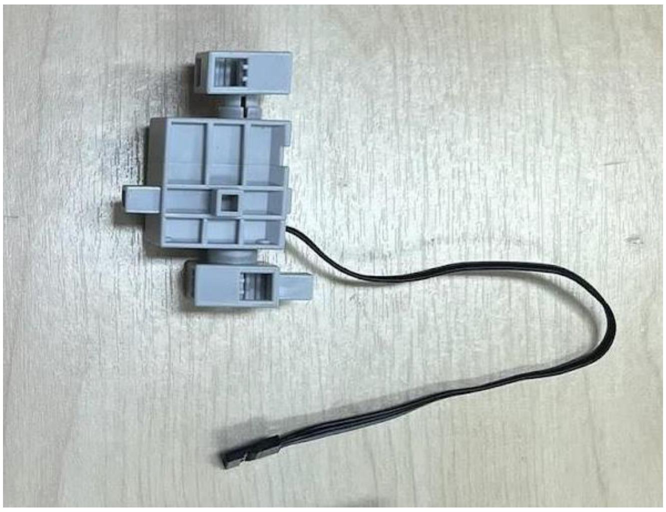
< back to contents

5.2 Let's Explore Motors and then, Design Your Robot

- From Task sequence, let's make clear the objective of your lesson by yourself.
- Tasks are focus on to distinguish the functions of DC motors and Servomotor.
- Guess the function of each command for a robot through analysis of given programme.
- Find the meaning of sequence commands through the running of programme.
- Utilise what learned for further challenges.

**Studuino is a programming environment by Scratch to control ArTeC Robo as block components. Following is a minimum explanation of major commands which we use.*

DC Motor with tires



Servomotor

Micro Computer

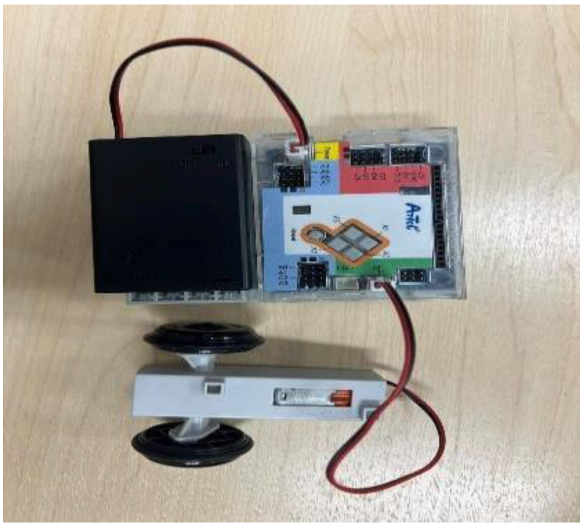
Battery Box

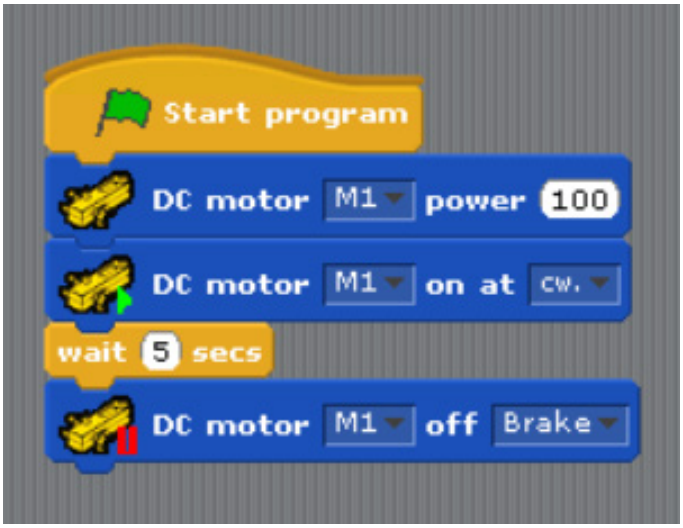
USB Cable

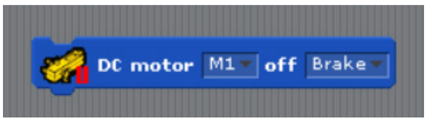
Limited Instruction for going to the task 2A:
How to connect a microcomputer, DC Motor, Servomotor, and computer. How to open Studuino Software.

Task 2A

Let's explore the function of commands for the DC motor from the given programme through changing the parameters on the commands. On the exploration, let's discuss the appropriate name of each command.





Command	Function	naming
		
		
		
		

Task 2B

Let's change the command order of Task 2A by yourself and guess how it moves and discuss it with others. Then, check it. For Example: If you change it like the right, what will happen?

Your changed programme 1:

Guessing and Discussing:

Checking:

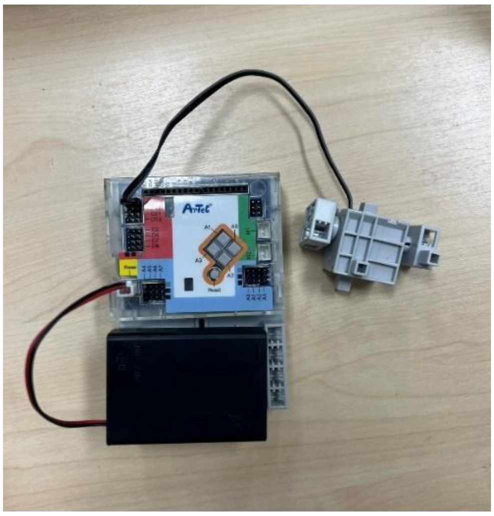
Your changed programme 2:

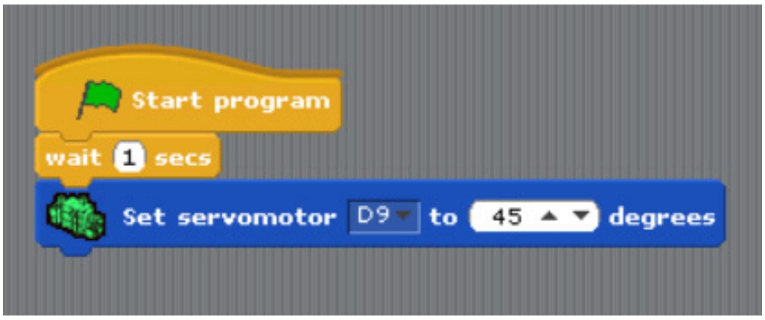
Guessing and Discussing:

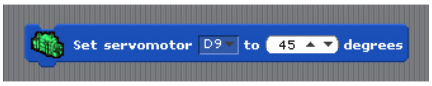
Checking:

Task 2C

Let's explore the function of commands for Servomotor from the given programme through changing the parameters on the commands. On the exploration, let's discuss the appropriate name of each command.





Command	Function	naming
 Set servomotor D9 to 45 degrees		

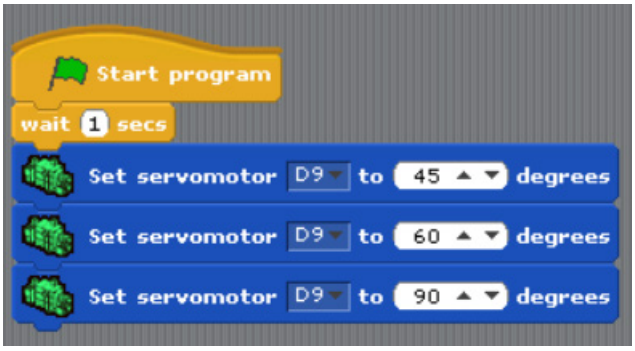
Did you find it?

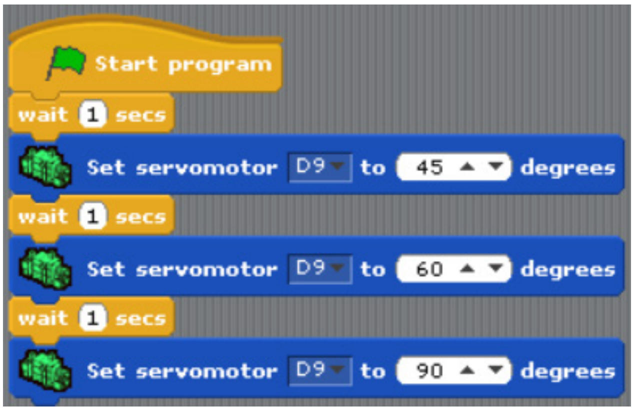
Task 2D

Explore the programming through adding commands and changing order by yourself.

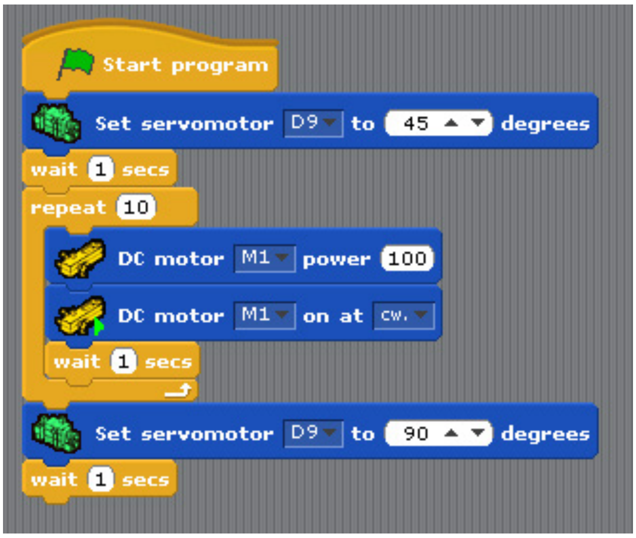
Such as:
Let's imagine what will happen!
'If I add commands what will happen?'
'If I change the commands sequence what will happen?'
Let's Guessing, and discussing, and then checking!

Sample 1:





Sample 2:



What do you want to do next? Task 2E

Now you can use motors which are controlled by a programme.
1. What Robot would you mind to design?
2. Let's draw your robot and how does it move?

Name of Your Robot:

Designing:

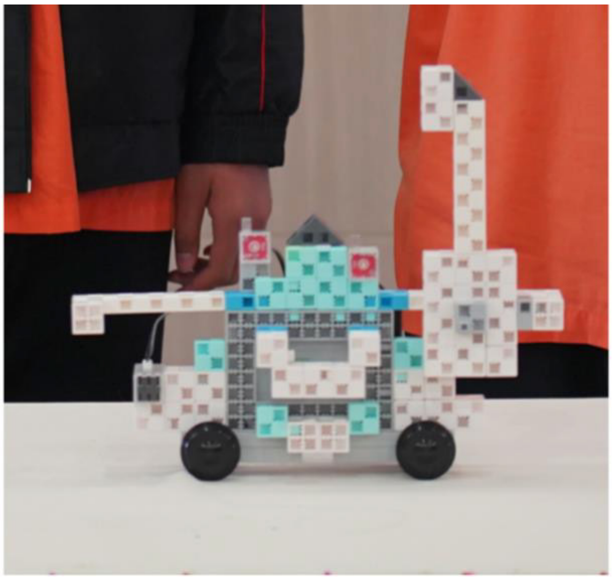
2. Let's assemble your robot by using a block.

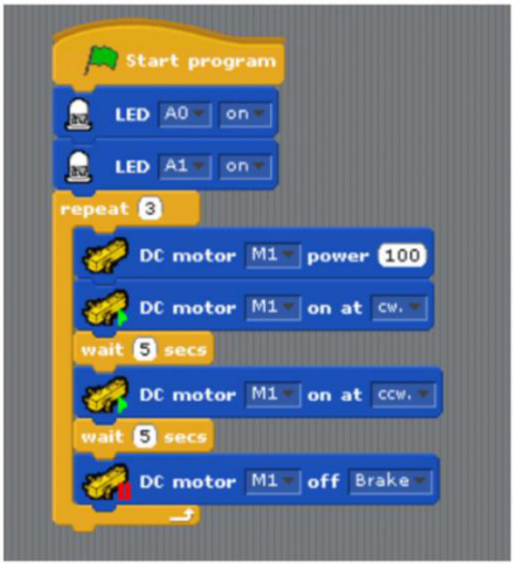
3. Let's write the programme, then run the programme, and record what happens.

4. Let's prepare your presentation by reflecting on your challenges, learning and what was fun.

What do you want to do next? Task 2F

Let's present your robot with explaining the Name of Robot and your challenges while demonstrating.





Additional questions and discussions in presentation session:

- ? Can you imagine my programme from the actions of robot?
- ? Can you imagine what will happen if you install my programme into your robot?
- ? Whose robot is attractive for you and why it is attractive for you?
- ? What have you challenged, learned, and enjoyed?

< back to contents

5.3 Let's Develop Your Robot!

Preparation:
From Task sequence, let's make clear the objective of your lesson by yourself.
Tasks are focus on to design own Robot by using DC motors and Servomotor:

1. Guess the function of each command for a robot through analysis of given Programme.
2. Find the meaning of sequence commands through the running of programme.
3. Utilise what learned for further challenges.

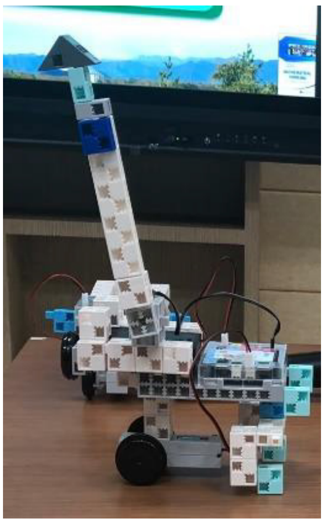
**Studuino is a programming environment by Scratch to control ArTeC Robo as block components. Following is a minimum explanation of major commands which we use.*

To Imagine Your Own Robot, a sample is a key.

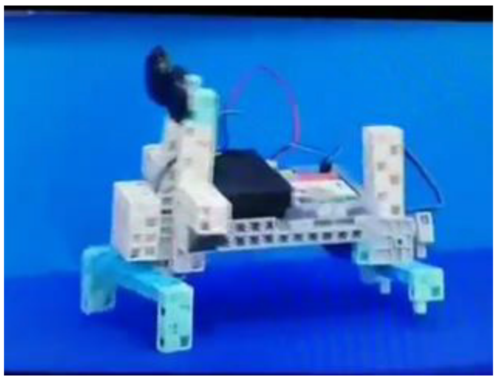
If it is the first time to develop a Robot, it might be fine to show one sample. Depending on the selection of samples, it becomes more challenging.

Sample 1: Tea service doll
Japanese Automata
(18 century)

Sample 2:
Digging machine

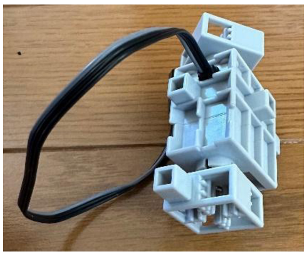


Sample 3:
Walking Cat



In minimum, to develop the car needs the following as well as blocks:

- DC Motor
- Three Tires: Two of them are rubber tires which are possible to rotate but one does not have rubber.
- Micro Computer (Studuino) & Battery And
- Servomotor



Limited Instruction:
• How to connect microcomputer and computer, DC motor, and Servomotor.
• How to open Studuino Software.

Task 3A

• What Robot such as machine cars would you like to develop?
• Let's draw the image of your robot.
• What function do you embed in your robots?

Name of Your Robot:

Designing:

Task 3B

Let’s see the parts of ArTeC Robo. When you develop your car by using the parts of ArTeC Robo, which parts are necessary to realise it?

1. In minimum:

2. For the better car, it needs more:

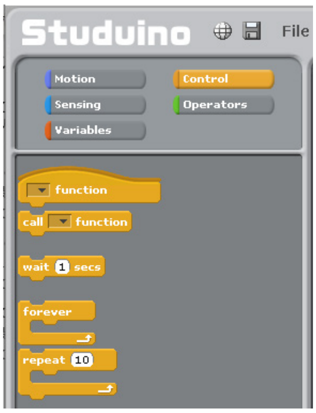
3. Let’s plan the possible steps to develop your car such as Robot-version I for step 1, Robot-version II for step 2, and so on.

If you do not know how to programme, do Task 3C and 3D. Otherwise, programme it by yourself.

Task 3C

Let's develop Robot-Version I.

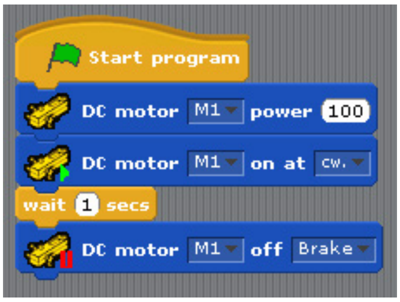
1. On your imaged robot, let’s assemble it with a combination of blocks.
2. Let’s develop the programme to move the car by using the commands on Motion and Control!

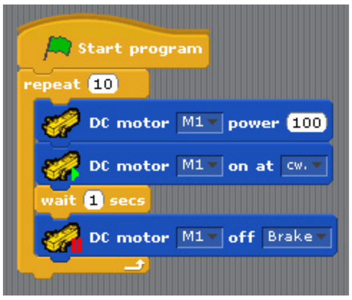


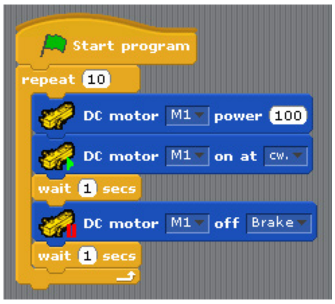
Task 3D

Read the programme at first, imagine and explain how it works.

1. Explain a), b) & c) below how it moves the car.

a) 

b) 

c) 

2. Which parameters would you like to change for what?
3. What is the possible on this minimum setting and what are the limitations.

Task 3E

Let's present your robot-version I to others and discuss what robot you would like to develop, what is difficult to challenge and how you overcome it.

Task 3F

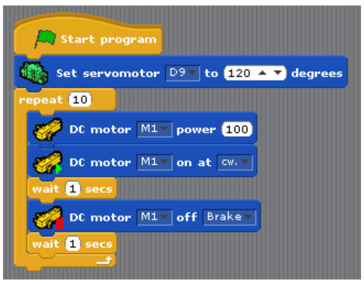
Renovate your Robot-version I to Robot-version II for adding motion by Servomotor.

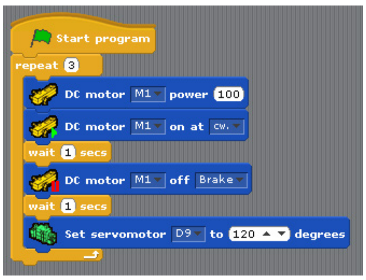
If you do not know how to use Servomotor, do Task 3G, otherwise do it by yourself.

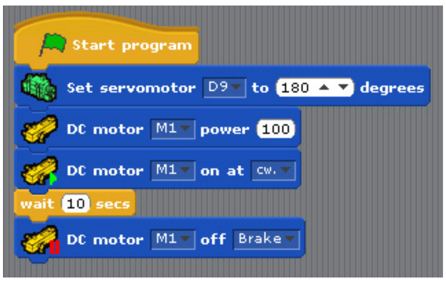
Task 3G

Let's develop the programme to use Servomotor for Robot-version II.

1. Read the programme a), b) and c) below and explain the differences and how function.

a) 

b) 

c) 

2. Does Robot-version II change the angle? If it works, why do you succeed? If not, what is the problem?
3. How do you realise the necessary motion in the limitation of block parts and so on?

< back to contents

Task 3H

Let's present your robot with explaining the Name of Robot and your challenges while demonstrating. And discuss what is fun with each other. And then, if you have another chance, what do you challenge in the next design?

Through every task and task sequence, what is enjoyable for students are collaborations to learn from others and share their creation with others such as each of their programme and robot motion as well as each of their achievements. If the programme is different, ask students when it applies to their robots and discuss how function it on their robots: It is the opportunity to utilise and generalise the programme to the other mechanism. There are various ways to function the same however only a few differences of the place of the command produces a huge difference.

For representing each student's personality and identity on their presentations, teachers and friends needs to listen his/her creation such as design and idea on 1). It is the opportunity to promote thinking by and for themselves and cultivate self-esteem which provide positive feedback for their creativity.

On these task sequence, there are no discussions about the parameters such as the duration how long shall we move DC Motor on which power and moving distance. Theoretically, it might have the relationship of proportionality. However, it does not exactly follow the proportionality even it is helpful idea to set the parameters.

The task which utilises the setting of parameters is to provide the race on the special course. However, it is not good task for the beginners from the perspectives of 1) and 2).

Let's specify the objective of class-activities for the Robot Programming.

These activities can be explained with several objectives such as followings:

For STEAM education:
To develop the robot, students engage in several translations among different systems such as Sketch-Designing, Block connecting, Programming and controlling Block-mechanism. In each translation between different systems, beginner learn each way of interpretation/explanation in each system and translation between systems. After they well learned these, they can do it by and for themselves much faster than beginners.

For Computational Thinking:
For development own robot, students solve various small problems for themselves in each system and in each translation between different systems. Students must analyse the process and find the necessary components which correspond between different systems. For example, to use DC-motor on the car, there are set of commands to be considered for the motion of block-mechanism. Students have to analyse the necessary motion on the block model and translate it into a sequence of commands. It is exploration of relationship between actual motion and a sequence of commands. Well learned students can use a sequence of commands as one command on their objective.

For Mathematical Thinking:
In every system, students must apply what they know. Real design image has a lot of curves however students ignore it for using the cuboid or rectangular solid block. For the controlling the motion, students must set the parameters with mathematical ideas such as proportionality.

For setting a value of the parameter, students need to select a parameter which may change as the result of another parameter and so on. Programme itself can be seen as a representation of mathematical reasoning. For example, let's think about to use someone's programme which developed for his/her specific robot to the others. Students can imagine how it works or not by interpreting the cords and re-present written reasoning in their minds. Programming robots includes the translation between mathematics and real world situation because a programme provide a solution for the real world problem. Here, the given programme for special robot is the object of generalisation and think analogically. Recursion of the same process which are necessary for complete induction in mathematics is easier to introduce on the robot programming.

Appendix

Spark Your Students' Thinking: The Revolutionary Era of LLMs

We stand on the precipice of a new educational paradigm, fueled by the groundbreaking capabilities of Large Language Models (LLMs) like ChatGPT and Gemini. These are not mere language assistants; they are transformative thinking tools poised to revolutionise your classroom and unlock your students' full potential.

Imagine a world where students don't wrestle with code syntax but focus on the core logic of their algorithms. A world where ideas flow freely, analysed, and refined by LLMs in real-time, fostering collaborative problem-solving like never before. This is the future LLMs bring, ushering in a new era of:

1. **Unleashing Creativity:** Break the shackles of technical roadblocks. Students can experiment with diverse solutions, iterating rapidly with LLM assistance, paving the way for ingenious inventions and artistic expression.

2. **Amplifying Collaboration:** Imagine brainstorming sessions enhanced by an LLM analysing each contribution, identifying synergies, and suggesting connections between seemingly disparate ideas. Collaboration becomes a symphony of thought, guided by a digital maestro.

3. **Building Confidence:** Struggling with syntax no longer saps motivation. LLMs translate ideas into code, empowering students to focus on their vision and build confidence in their problem-solving abilities.

4. **Democratising Access:** Technical limitations become non-existent. Students of all backgrounds can explore fields like programming and robotics, empowered by an LLM that speaks their natural language and helps them translate it into reality.

5. **Nurturing Critical Thinking:** The LLM becomes a thought-sparring partner, challenging assumptions, refining arguments, and guiding students towards deeper understanding and well-reasoned solutions.

By harnessing the power of LLMs, we can nurture a generation of innovative thinkers, confident problem-solvers, and collaborative creators, ready to shape a brighter future. Let's unlock the potential within every student and build a world where ideas, amplified by LLMs, truly take flight.

Computational Thinking (CT)

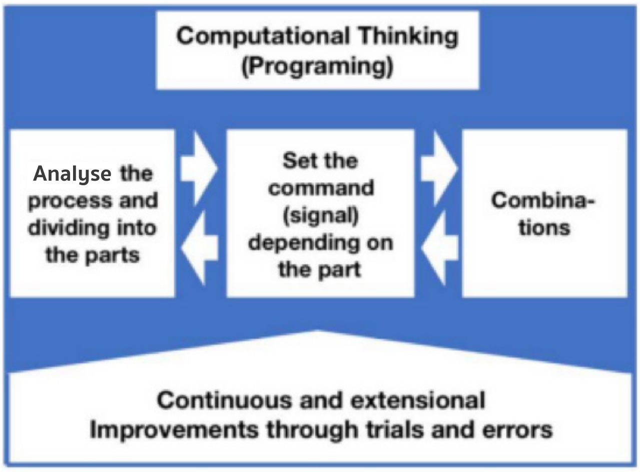


Figure 1: Programming Thinking

In the past decades, Computational Thinking has been explained as Programming Thinking which is necessary to utilise computers for problem solving, however, nowadays, it is generally useful to solve the problem with support with or without computers. In the era of Digital Transformation (DT) by the emergence of Generative AI which allows us to use AI with natural language, Computational Thinking can be utilised anywhere by anyone. Even for programming in Informatics, Generative AI produces and supports necessary programming if the prompt engineers well ordered it by natural language. Now, it is necessary for all of us to work like engineers who are able to use natural language depending on their project work and so on. Computational Thinking has been a part of mathematical thinking to mathematically apply the numerical operation to solve problems (Isoda, Katagiri, 2012) when we represent it by mathematical/computational representation. Computational Thinking, even if we utilise it with natural language, is characterised with three main pillars: Algorithmic thinking, Computational Modeling, and Machine Learning (Roberto, Isoda, 2021).

Algorithmic Thinking is a meccano set or a game of blocks, whose basic pieces or bricks are commands. Mechanisms or buildings are built on them, which allow different solutions to be built. Algorithmic Thinking is a base of programming thinking.

A first key in algorithmic thinking is search. Task 1A, 2A, and 3A of Chapter 2 introduce searches for objects. Searches are specified with different types of conditions. The most basic are those that instruct satisfying membership in a category, such as a clothing category. Task 1A, 4A, and 5A of Chapter 2 also include searches with properties of a spatial nature. Another central concept is that of lists or arrays. Task 4A of Chapter 2 contains the search for an element of a list or array with a certain spatial property or a cardinal property (related to the number of elements). Task 8A of Chapter 2 cycles through arrays looking for one with a greater or lesser number of elements. Task 9A requires differentiating within the lists of the elements that satisfy a topological feature. In this case it is furthest to the right. It also has a feature of the elements of the lists that satisfy a cardinality condition (more ducks). Task 11A of Chapter 2 uses quantifiers and arrays, but with fish in fish tanks, and on Task 10A it does so with inanimate objects such as balls in boxes. In this activity (and the one on Task 4A), a random command is hidden, since the number of balls is not completely specified. It only has to be bigger than a certain number. On Task 12A of Chapter 2, about the smallest chicken of the largest hen, the search goes through two sets or arrays, some included in others, with opposite-order relationships.

A central activity in algorithmic thinking is the cognitive process of decomposing a problem into simpler problems, down to problems that require only a few commands. An example is logical connectors. For example, to find a hidden object, where different characters give different clues. There are examples of this challenge in various activities in these colouring books. Some of them reach a definitive solution as on Task 13A and 14A, of Chapter 2. Task 14A of Chapter 2 includes negations of propositions. In this type of activity, the notion of probability could be easily included. For example, searching for the most probable places where an object is hidden. Connectors can also be existential and universal quantifiers. For example, to specify that at least two blue balls must be coloured in every box, as illustrated in the activity on Task 10A of Chapter 2, and also in (Araya, 2021a).

Another central cognitive process of algorithmic thinking is serially linking commands, either in sequences, in cycles, or combinations of sequences and cycles. A daily use case for this is Google Map recommendations for getting from one place to another in the city. Google Maps also monitors the status of routes and possible accidents to adjust recommendations in real-time. The example in the book is 2.4 Route Finding and 2.5 Running Route Design.

Then, there is the notion of recursion. These mechanisms made of commands become commands in turn. Task 15A of Chapter 2 contains a typical recursion: 'Paint all the shapes that do not contain other shapes within them, and do it so that neighbouring shapes are different colours'. Many examples in Chapter 3 used recursion.

Computational modeling is another of the pillars. An example is the modelling of the navigation or migration of a cell or microorganism. It moves locally with a command to the neighbouring cell with more nutrients. And so it continues executing that sequence of commands until it can no longer improve (Araya 2022). This is an example of one of the most used algorithms in AI: the deepest descent algorithm (Araya, 2021b). This type of activity is found such as 2.4 Route Finding, 2.7 Design with Patterns, 2.8 Chicken Farms, 2.10 Connections. For example, on 2.10, the algorithm for Ladder Lottery is the same as Hanoi’s tower as well as Yarn-Phone Network. Examples in Chapter 3 visible programming such as someone’s programme can also work on others' machines, and so on.

The third pillar is Machine Learning which is necessary to use a set of selected appropriate examples as for trainers. To be a trainer of Machine Learning, everyone has to work like teachers who fix and produce a set of selected appropriate examples. It implies that children become teachers. Most examples in Chapter 2 follow the task sequence at first to learn something and then engage in further tasks at the end. Children are necessary to discuss about how their produced questions at the final task at the end are similar to the previous tasks or how different. Depending on the perspective, their meanings of similarity may change however they might develop the custom to produce questions by and for themselves in relation to what they learned.

We imagine all these examples of activities as unplugged. This means imagining the solution on machines, on boards, and with very simple agents. All these elements can be run on a computer with programming and represented with mathematical representation.

Mathematical Thinking (MT)

In Western history, mathematics originated from ‘mathema’ as the subject for learning in Ancient Greece. It implies that any subjects of learning until Ethics for the subjects called mathema to train the ways of thinking in their mother tag, Greek language as Regional Language. The dialectic logic, ‘if your conclusion/saying is true, what will happen?,’ was also called the method of analysis (or Socratic method in Education).

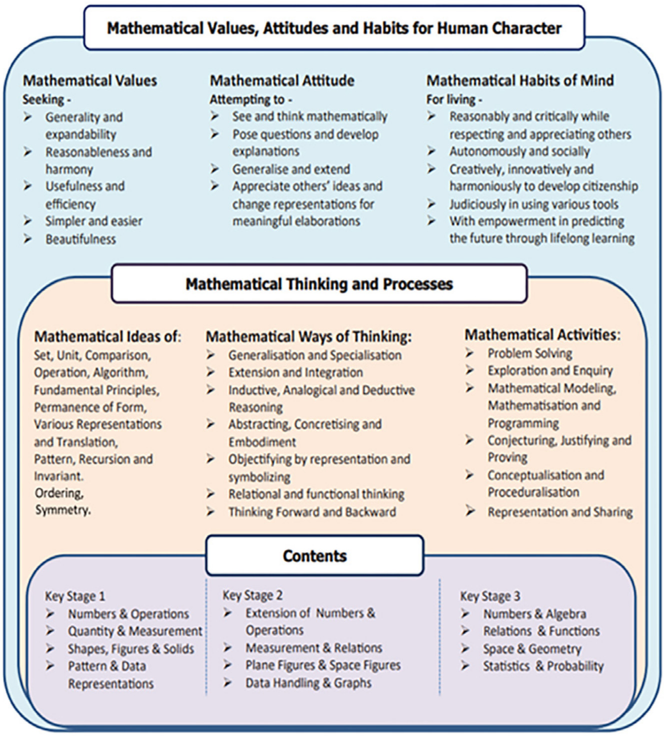


Figure 1. Revised CCRLS Framework in Mathematics

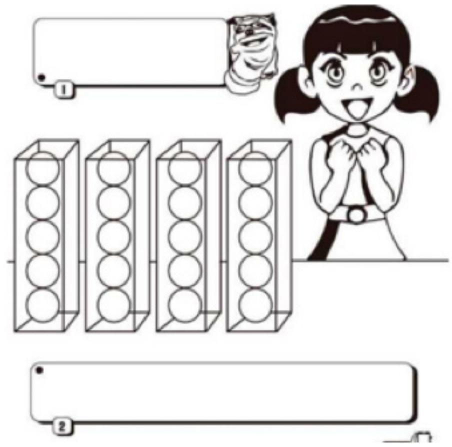
Since the Era, mathematics has been the subject to develop mathematical thinking (Inprasitha, Isoda, Roberto; to appear).

Eventually, Current meaning of mathematics met revolution in the Era of Descartes when he promoted the use of algebraic language to subjects such as music, astronomy, geometry, arithmetics and so on. Even though Algebraic representations became the language for science, it produced the necessity to be learned as a unique Universal Language in the world.

Generative AI can be used by Natural Language. That's why it is necessary to review mathematics with Natural language and develop mathematical thinking to be used for various problem solving in our life.

In the SEAMEO Common Core Regional Learning Standards (CCRLS) framework in Mathematics by Isoda, Guan & Teh (2023), Mathematical Thinking is characterised by the related terminology on mathematical values, attitudes, habit of mind, ideas, ways of thinking and activities. It is enhanced through the repetition of appropriate processes to develop mathematical thinking. Such processes can be explained by the contexts of Real World situation and mathematical task sequence. In both contexts, reflection and appreciation are keys to recognise the ways of thinking and values. Computational Thinking is also clarified by using the terms of mathematical thinking and representations.

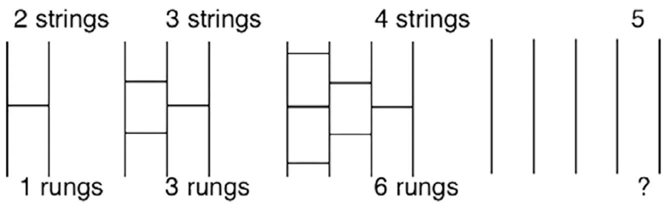
The Context on Real World Situation



On 1.10 Ball Painting Task 10A and 10B for the left, students must explain the collaring activity to the others. For explaining exactly, students need to re-present it exactly. Children can use daily words, however left or right, front or back, upper or lower, 3rd row, 2nd column were teaching content in mathematics. If we use mathematical representations, such as ordered pairs or matrices, we can explain it exactly. And if we try to represent it by mathematics, we can discuss it as the task for mathematics. Mathematical ways of questioning, we can explore the situation mathematically. For example, how many possible solutions we have in the given situations. For programming, mathematical language learned in mathematics class is necessary.

The Context on the Mathematical Task Sequence

On the Task sequence 2.10 Connections, it aimed to develop inductive reasoning. For example, on Ladder Lottery, if we think from the simple case and increase the number of strings, one by one, we can find a recursive structure on rungs. It is one of the general algorithms to produce the reverse order. The found algorithm has a beautiful pattern like a Pyramid. In the task sequence, there are a number of opportunities to recognise and use the terminology for Simplification (Specialisation) and Generalisation, Inductive reasoning, Recursion, Algorithm, Invariant, Pattern, Ordering, Minimising and Beautifulness. Like 'Wow, it looks Pyramid,' students can re-present these words by their words and then, teachers can paraphrase it as 'Pyramid? Really?' 'Could you check other cases' 'Yes, it is! How beautiful the pattern is!' Teachers can re-word students' words in which students are able to recognise and represent it by and for themselves.



In both contexts, the opportunity for reflection and appreciation is necessary to develop mathematical thinking and computational thinking. In examples, the final task asked students to pose further questions or activity for themselves. It is an opportunity to reflect on and appreciate their experiences in previous tasks. All activities in this book provide students such opportunities for reflection and appreciation for making clear on their ways of thinking, and valuing by and for themselves.

< back to contents

STEM Thinking

The acronym 'STEM,' representing Science, Technology, Engineering, and Mathematics, originated from the National Science Foundation (NSF) in the early 1990s. This formulation by the NSF was a deliberate initiative aimed at addressing the demands of education, economy, and society, demonstrating an overarching strategy to fortify educational systems and develop a resilient workforce equipped to tackle future challenges.

STEM Thinking refers to the intellectual approach embraced within Science, Technology, Engineering, and Mathematics (STEM) education. It embodies a pedagogical shift towards integrating these disciplines, focusing on solving complex problems, understanding multifaceted systems, and fostering innovation through interdisciplinary learning.

Developing STEM thinking involves cultivating a mindset that integrates the principles of Science, Technology, Engineering, and Mathematics to solve problems, understand complex systems, and innovate. Here are key strategies to foster STEM thinking:

1. **Interdisciplinary Learning:** In contrast to traditional education models that often treat scientific subjects in isolation, STEM encourages the fusion of science, technology, engineering, and mathematics. This integration enables students to make meaningful connections between disciplines, enhancing their understanding and application of each in real-world contexts.

2. **Emphasis on Problem-Solving:** STEM education prioritises critical thinking and problem-solving skills. It typically employs a four-phase instructional model:

   - Research: Understanding the problem and its context.
   - Investigation: Examining the variables influencing the problem.
   - Solution Development: Designing and creating solutions.
   - Evaluation and Communication: Assessing solutions and presenting them to authentic audiences.

This model encourages students to apply their interdisciplinary knowledge to develop practical solutions to complex challenges.

3. **Developing Higher Order Thinking:** STEM education fosters higher-order thinking by engaging students in questioning and discourse that prompts them to explain and justify their reasoning. This process not only deepens their conceptual understanding but also enhances their analytical and evaluative skills.

4. **Collaborative Learning:** Collaboration is a cornerstone of STEM education. It provides students with opportunities to develop teamwork and leadership skills, exchange ideas, and collectively construct solutions.

5. **Reflective Practice:** Encouraging students to record their observations, ideas, and reflections through journaling or other means of documentation enhances their learning experience. This practice promotes deeper engagement and fosters metacognitive awareness, allowing students to monitor and reflect on their learning process.

6. **Integrating Technology:** In STEM education, technology is utilized not only as a learning tool but also as a subject of study. Students are encouraged to understand, use, and manipulate technology, which is vital for success in many STEM fields.

7. **Applying Real-World Connections:** Making learning relevant by linking STEM subjects to real-world scenarios is essential. Discussing current scientific research, technological innovations, engineering challenges, and practical applications of mathematics makes the learning process engaging and pertinent.

Worksheets in Chapter 3 are developed to encourage the practice of these concepts to create a STEM Mindset in the students. Worksheet 3.1 presents the STEM learning process as an additional activity expanded from the use of Coloring Books. Worksheets 3.2 encourage the teachers and students to think beyond the problem using integrated STEM approach. Worksheets 3.3 through 3.6 are foundational, focusing on the basics of Artificial Intelligence technology, beginning with the concept of decomposition and relating it to everyday activities. These worksheets promote collaborative learning, encouraging students to share and discuss their ideas, allowing them to explore how peers may interpret their thoughts differently. This collaborative process is not only engaging but also serves as a valuable tool for reflecting on their own understanding and approaches.

STEM thinking not only cultivates innovation and creativity through the synthesis of technical skills and creative thought, but also bolsters adaptability. These skills, applicable across a variety of sectors beyond traditional STEM fields, are increasingly vital in our dynamically evolving job market. STEM education places students at the forefront of technological and innovative progress, equipping them for the careers of tomorrow in a world where technology's influence continues to expand. The escalating demand for professionals well-versed in STEM underscores the critical nature of these educational practices in maintaining a competitive edge in the global economy, marking STEM education as not just beneficial but essential.

Note:

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