Co-funded by
the European Union

Framework of the interactive Tasks

The results are based on the work within the project "Computational Thinking and Mathematical Problem Solving, an Analytics Based Learning Environment" (CT&MathABLE). Coordination: Prof. Valentina Dagienė, Vilnius University (Lithuania). Partners: Ankara University (Türkiye), Eötvös Loránd University (Hungary), Gedminų Progymnasium (Lithuania), KTH Royal Institute of Technology (Sweden), Özkent Akbilek Middle School (Türkiye), University of Basque Country (Spain), University of Turku (Finland),. The project has received co-funding by the Erasmus+.

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General overview

This framework is intended to provide conceptual understanding about interactive tasks that addresses informatics topics and computational thinking skills. Being interactive in nature, not only broadens the scope of the questions but also lets teachers present different insights to any problem. Preparing questions for specific goals for the assessment is not easy. Thinking about the classical assessment approaches like multiple-choice, it is obvious that it narrows the insight and thinking skills of the students by making them think and try with limited answers, even lead to guessing or trying answers instead of solving the problem. With open-ended and trial-error type of questions, students are provided with more opportunities to think and reflect about the problem.

Thus, teachers should be preparing such problems that fosters creativity and improves thinking skills of students. With these in mind, this module is prepared to provide guidelines and introduce theories that can be helpful for teachers while designing and developing interactive Bebras tasks. Relying on well-known and widely accepted guidelines and educational theories will make the process easier and result in more effective problems for making students think computationally.

Target groups

This document is intended to provide a framework for teachers and educators who create interactive learning content, especially short tasks for learning informatics concepts and computational thinking skills. Teachers of any subject field, also in STEM disciplines, can use this framework while designing and developing interactive Bebras tasks which are problems to solve.

Keywords
Computational thinking, informatics, interactivity, active learning, multimedia, Mayer's principles, Blooms' taxonomy, cognitive load.

1. Introduction

Richard E. Mayer is a renowned psychologist and researcher in the field of educational psychology. He has developed a set of principles that provide valuable guidance for designing multimedia materials that enhance learning outcomes. These principles are grounded in cognitive psychology and aim to leverage the way the human brain processes information for more effective learning experiences.

Richard Mayer's cognitive theory of multimedia learning is based on the assumption that humans have a limited capacity to process information in their working memory, and that this capacity can be easily overloaded if too much information is presented at once. Mayer suggests that learning is an active process where individuals actively construct their own knowledge based on the information they receive. Mayer also argues that multimedia materials that use both visual and auditory channels can enhance learning because they can engage multiple senses and create connections between different sources of information.

Mayer's theory is rooted in cognitive psychology and focuses on optimising the design of multimedia materials to align with the limitations and capabilities of human cognitive processes. Here's a bit more detail on some of the key points you mentioned:

Limited Working Memory Capacity: Mayer's theory acknowledges that working memory, which is responsible for temporarily holding and processing information, has a limited capacity. When designing instructional materials, it's important to avoid overwhelming learners with an excessive amount of information. This is why Mayer emphasises the importance of presenting information in a structured and organised manner to prevent cognitive overload.

Active Learning: Mayer's theory highlights the learner's active role in constructing knowledge. Instead of passively absorbing information, learners engage in cognitive processes such as selecting, organising, integrating, and elaborating on the presented material. Mayer's principles guide designers in creating materials that facilitate these cognitive processes, fostering deeper understanding and knowledge retention.

Multimedia Principles: Mayer's emphasis on using both visual and auditory channels in multimedia materials is based on the idea that leveraging multiple sensory pathways can enhance learning. Visuals and narration, when synchronised appropriately, can work together to help learners make meaningful connections between different types of information. This dual-channel approach taps into the brain's natural ability to process and integrate information from various sources.

Cognitive Load Theory: Mayer's theory aligns closely with cognitive load theory, which posits that instructional materials should be designed to manage the cognitive load imposed on learners. Cognitive load refers to the mental effort required to process information. Mayer's principles, such as the coherence and signalling principles, aim to reduce extraneous cognitive load by streamlining the presentation of information and guiding learners' attention to key points.

Incorporating Mayer's cognitive theory of multimedia learning into instructional design practices can lead to more effective and efficient learning experiences. By respecting the limitations of working memory, promoting active learning, and harnessing the benefits of multimedia, educators and designers can create materials and problems that align with how our brains naturally process and internalise information.

Besides, it is important to align the difficulty level of any material and problem according to age group and cognitive level. Thus, we should have clear criteria and guidance in doing so. This is the point where we can use Blooms' Taxonomy.

Blooms' Taxonomy: Bloom's taxonomy is a set of three hierarchical models used for classification of educational learning objectives into levels of complexity and specificity. The three lists cover the learning objectives in cognitive, affective, and psychomotor domains. For cognitive domain, the six levels of the Taxonomy included (1) knowledge, (2) comprehension, (3) application, (4) analysis, (5) synthesis, and (6) evaluation.

Mayer proposes that learning is most effective when it is meaningful and relevant to the learner's prior knowledge and experience. He suggests that learners must also be able to organise and integrate new information into their existing knowledge structures, a process he refers to as "schema construction."

Based on these assumptions, Mayer developed 12 principles of multimedia learning to guide the design of effective multimedia materials for learning. These principles are summarised below:

1. **Multimedia Principle**: People learn better from words and pictures than from words alone.
2. **Modality Principle**: Use both visual and auditory channels for presenting complementary information.
3. **Redundancy Principle**: Avoid redundant presentation of information in both visual and auditory formats.
4. **Coherence Principle**: Exclude extraneous material not relevant to the learning goal.
5. **Signalling Principle**: This principle suggests that cues or signals should be used to highlight important information, and to help learners understand the structure of the material.
6. **Spatial Contiguity Principle**: Present relevant words and pictures close together on the screen or page.
7. **Temporal Contiguity Principle**: Present spoken words concurrently with corresponding graphics.
8. **Segmenting Principle**: Break the multimedia lesson into manageable segments with clear start and stop points.
9. **Pre-training Principle**: Provide learners with necessary information before the multimedia lesson to optimise learning.
10. **Image Principle**: Use meaningful, relevant graphics that contribute to the understanding of the content.
11. **Personalization Principle**: Use conversational language and include human voice in narration.

12. **Voice Principle**: Use a friendly human voice for narration rather than a machine-generated voice.

Overall, Mayer's principles provide practical guidance for creating effective multimedia materials for learning. By following these principles, designers can create materials that engage learners and promote deeper understanding and retention of information.

To understand Mayer's theory of multimedia learning, it's important to start with his assumptions about how people learn. Mayer assumes that people have limited capacity to process information in their working memory, and that this capacity can be easily overwhelmed if too much information is presented at once. He also suggests that learning is an active process where individuals construct their own knowledge based on the information they receive. Additionally, Mayer argues that learning is most effective when it is relevant to the learner's prior knowledge and experience, and that learners must be able to organise and integrate new information into their existing knowledge structures.

This current framework will build on all of these conceptual facts and principles to provide a roadmap for preparing interactive tasks. Hence, each of the theory and principle will be explained in detail in the following sections.

2. Information Processing

Mayer's cognitive theory of multimedia learning makes three assumptions about how humans process information:

1. The dual-channel assumption,
2. The limited-capacity assumption, and
3. The active-processing assumption.

1. The Dual-Channel Assumption

According to Mayer (2009), the dual-channel assumption dictates that "humans possess separate channels for processing visual and auditory information" (p. 63). The first is the visual–pictorial channel, which processes images seen through the eyes (including words displayed on a screen). The other channel is the auditory–verbal channel, which processes spoken words.

2. The Limited-Capacity Assumption

The limited-capacity assumption suggests that humans have a hard limit on the amount of information they can process at any given moment. This is probably intuitive to anyone who's sat in a sports bar and tried to watch several games at the same time or tried to listen to the news while having a conversation.

Although it's difficult to nail it down, Mayer suggests that most people can maintain maybe five to seven "chunks" of information in working memory at a given time (p. 67). He also indicates that individuals at the higher end of that range may have stronger metacognitive strategies, which allow them to manage their limited cognitive resources more efficiently.

3. The Active-Processing Assumption

The active-processing assumption asserts that humans don't learn by just passively absorbing information. Instead, they need to engage in active cognitive processes, namely identifying and selecting relevant material, organising it into visual and/or verbal models, and integrating those new models with prior knowledge (p. 70). The cognitive theory of multimedia learning fundamentally argues against a "knowledge transmission" approach to learning in favour of a student-centred "knowledge construction" model. Students, he argues, are not "empty vessels" waiting to be filled up with information but must instead work to synthesise words and pictures into meaningful information that is stored in long-term memory.

3. Cognitive Load Theory

Mayer's cognitive theory of multimedia learning builds upon cognitive load theory, which suggests that the capacity of our working memory is limited, and that we can only process a certain amount of information at any given time. According to Mayer's theory, the kind of information that we encounter during learning can lead to one of three different types of cognitive processing:

1. **Selective processing**: This type of processing occurs when learners attend to only one aspect of the information presented, while ignoring other information. This happens when the information is simple and easy to process.
2. **Coherent processing**: This type of processing occurs when learners integrate new information with their existing knowledge. Learners try to make sense of new information by connecting it to what they already know. This type of processing is considered deeper and more meaningful than selective processing.
3. **Generative processing**: This type of processing occurs when learners actively engage with the information presented, creating new mental representations of the information. This type of processing is considered the most effective for learning, as it requires learners to analyse and synthesise the information in order to generate new knowledge and understanding.

Mayer's theory suggests that multimedia presentations can be designed to facilitate these different types of processing, which can ultimately enhance learning outcomes. For example, by presenting information in a way that promotes generative processing, learners are more likely to retain and apply the information to real-world situations.

Extraneous load (also known as "extraneous processing") refers to wasted cognitive effort on material or details that don't support the learning outcomes. Instructors can minimise extraneous load by focusing narrowly on the essential material and eschewing everything that could distract learners (such as needless animations or irrelevant information).

Intrinsic load (also known as "essential processing") refers to the cognitive effort required to represent the material in working memory and is based on the complexity or difficulty inherent to the learning materials. Instructors should aim to manage intrinsic load by chunking their materials and identifying technical terms in advance.

Germane load (also known as “generative processing”) is the effort required of learners to actually understand the material and is strongly affected by their motivation. Instructors should optimise germane load by scaffolding learning and pacing material appropriately.

In some ways, we can see cognitive load theory as being an extension of the limited-capacity assumption. Given that we have a limited ability to process information in real time, instructors should aim to construct multimedia that manage intrinsic load, optimise germane load, and minimise extraneous load to ensure maximum storage in long-term memory. So while Mayer’s principles provide insight on how to effectively construct multimedia messages for learning, each also maps to a best practice in managing cognitive load.

In short, the cognitive theory of multimedia learning assumes that the human mind is a dual-channel, limited-capacity, active-processing system, and that presenters must construct multimedia messages to manage all three types of cognitive load accordingly. Mayer adopts a constructivist view of learning in which multimedia are not simply information delivery systems, but rather cognitive aids for knowledge construction (p. 14).

4. Principles of Multimedia Learning

Now that we’ve established the cognitive psychology foundation, let’s move on to summarising each principle.

4.1 Principles That Minimise Extraneous Load

4.1.1 The Coherence Principle

“People learn better when extraneous material is excluded rather than included.” (p. 89)

The coherence principle is about minimising extraneous processing. Instructors should not include information in their multimedia messages that will not be assessed, is merely intended to “spice up” the presentation, or distracts from learning goals overall.

Mayer also warns against including **seductive details** (interesting but irrelevant material that the presenter might include to re-engage the audience or create emotional responses), which the audience often retains better than the intended core message (p. 97). Given that learning is an active process, these extraneous details may interfere with learners’ construction of mental models to represent the material.

To address this principle:

- Include only graphics, text, and narration that support learning goals (i.e., don’t use decorative images or supplemental materials).
- Don’t use background music.
- Use simple visuals (as opposed to realistic or detailed visuals).

4.1.2 The Signalling Principle

“People learn better when cues that highlight the organisation of the essential material are added.” (p. 108)

Particularly when multiple pieces of information are on-screen, learners need to know what to pay attention to, where they are in the presentation, and how to integrate the information to construct their own mental models. Accordingly, the signalling principle recommends that instructors add cues that direct learners’ attention to salient material. Mayer is careful to point out that this can be overdone, so presenters should use signals sparingly.

To address this principle:

- Use arrows, highlighting, and other signals to draw attention to important information.
- Include an **advanced organiser** (content that presents the organisational structure of your multimedia presentation) and refer back to it when you advance to a new section.

4.1.3 The Redundancy Principle

“People learn better from graphics and narration than some graphics, narration, and printed text.” (p. 118)

Many multimedia presentations involve a combination of spoken words, graphics, and on-screen text. However, the redundancy principle suggests that multimedia messages are most effective when learners encounter just spoken words and graphics. When instructors include text on-screen, they risk overwhelming their learners’ visual channels with both pictures and words, and inadvertently direct their cognitive processes to resolving differences between the spoken text and the printed text.

To address this principle:

- When delivering a narrated presentation, use either graphics or text, but not both.
- Minimise the use of text during a narrated presentation.

4.1.4 The Spatial Contiguity Principle

“Students learn better when corresponding words and pictures are presented near rather than far from each other on the page or screen.” (p. 135)

The specifics of the spatial contiguity principle may be somewhat more intuitive than Mayer’s other principles. In short, it suggests that instructors should keep text (such as labels or captions) near to the graphics that they describe. If they do so, they minimise the cognitive effort that learners must expend to align the meaning of text and images themselves. Thus, instead of scanning the screen to make such connections, learners can devote that cognitive effort to integration and connection building.

To address this principle:

- Place text in close proximity with the graphics it refers to.
- Provide feedback close to the questions or answers it refers to.

- Present directions on the same screen as an activity.
- Have people read any text before beginning an animated graphic.

4.1.5 The Temporal Contiguity Principle

“Students learn better when corresponding words and pictures are presented simultaneously rather than successively.” (p. 153)

To maximise learning, the temporal contiguity principle dictates that narration and animation should be delivered concurrently. For example, students shouldn’t hear about a process and then watch an animation of it afterward; instead, instructors should time the narration to play along with the animation.

To address this principle:

- Time narration appropriately to play along with animations.

4.2 Principles That Manage Intrinsic Load

4.2.1 The Segmenting Principle

“People learn better when a multimedia message is presented in user-paced segments rather than as a continuous unit.” (p. 175)

Mayer’s experiments involved presenting asynchronous multimedia messages to research subjects (messages that largely focused on describing processes, such as how lightning forms). He determined that when students had the ability to control the pace of the lesson, they performed better on recall and transfer tests. Thus, the segmenting principle has two implications: (a) users should have control over the pace of the multimedia lesson, and (b) instructors should chunk material appropriately to allow for adequate processing on each slide or screen.

To address this principle:

- Allow users to control the pace of the lesson, such as speed controls or “next” buttons.
- Break down long segments of material into smaller pieces.

4.2.2 The Pre-Training Principle

“People learn more deeply from a multimedia message when they know the names and characteristics of the main concepts.” (p. 189)

The necessity of managing essential (or intrinsic) load suggests that it’s easy for novice learners to become overwhelmed by the quantity or complexity of the information in a multimedia message. The pre-training principle accordingly recommends that instructors define key terms or concepts before diving into descriptions of processes. Otherwise, students will be stuck trying to learn a process’s component parts while also attempting to build a mental model of the process itself, which may hinder learning. In essence, pre-training is about scaffolding learning and helping students establish appropriate prior knowledge before beginning a multimedia lesson.

To address this principle:

- Define key terms (such as names, definitions, locations, and characteristics) before beginning a process-based presentation, either in a separate presentation, handout, or similar material.
- Ensure people know how to use a tool (such as Excel) before asking them to perform learning activities within it.

4.2.3 The Modality Principle

"People learn more deeply from pictures and spoken words than from pictures and printed words." (p. 200)

The dual-channel and limited-capacity assumptions lead in part to the modality principle, which recommends that instructors use narration instead of on-screen text when pictures are present. If multimedia messages contain pictures and on-screen text, the combination may overwhelm learners' visual channels. Instead, instructors should only speak words (rather than include them on-screen), which spreads the load across both the visual and the verbal channels (also known as "modality offloading"; p. 204).

To address this principle:

- During a narrated presentation with graphics, avoid using on-screen text, unless it:
    - Lists key steps
    - Provides directions
    - Provides references
    - Presents important information to non-native English speakers

4.3 Principles That Optimise Germane Load

4.3.1 The Multimedia Principle

"People learn better from words and pictures than from words alone." (p. 223)

You could argue that the multimedia principle is a starting point for all the other principles, given that it indicates that learners perform better when exposed to words and pictures rather than just words. Given that multimedia presentations may or may not be narrated, it's important to underscore that the "words" in this case should be either printed or spoken, but not both (in keeping with the other multimedia principles). Effectively leveraging pictures and words together fosters generative processing.

To address this principle:

- Include images to illustrate key points.
- Ensure that all images enhance or clarify meaning (rather than being purely decorative).
- Favour static images over animations (with some exceptions).

4.3.2. The Personalization Principle

"People learn better from multimedia presentations when words are in conversational style rather than formal style." (p. 242)

According to the personalization principle, having a more relaxed tone in an online class can actually positively impact learning. Thus, instructors should avoid stiff, academic language, and instead use more approachable colloquial language. Try to think of the presentation as a one-on-one conversation with each student. Informal language has the effect of creating social cues within the presentation that "prime the activation of a social response in the learner—such as the commitment to try to make sense out of what the speaker is saying" (p. 247).

To address this principle:

- Use contractions.
- Use first and second person ("I," "you," "we," "our," etc.).
- If using a script, try to make an extemporaneous-sounding performance.
- Use polite speech ("please," "you might like to," "let's," etc.).

4.3.3 The Voice Principle

"People learn better when narration is spoken in a human voice rather than in a machine voice." (p. 242)

The voice principle is perhaps the oddest of the group, but it is still worthy of mention, particularly given the speed at which technology is developing. This principle suggests that narration is better done by a human than a computer. Mayer stresses that the research on this principle is still preliminary.

To address this principle:

- Include narration that's performed by a human rather than a computer.

4.3.4 The Image Principle

"People do not necessarily learn better when the speaker's image is added to the screen." (p. 242)

The image principle is the only multimedia principle that's not affirmative in its phrasing. It states that including an image of an instructor's "talking head" during a multimedia presentation doesn't *necessarily* improve learning outcomes. Just as with the voice principle, Mayer is careful to point out that the research on the image principle is still preliminary. Nonetheless, early results suggest that you don't necessarily add value by showing your face during a narrated presentation.

To address this principle:

- Avoid including a video of yourself during an asynchronous multimedia presentation containing pictures and words.
- Consider including your face when:

- There are no words or pictures.
- You wish to establish instructor or social presence.

5. Boundary Conditions and Discussion of Mayer's Theory

Mayer is careful to set "boundary conditions" for his multimedia principles—situations in which the principles may not apply as strongly. For example, with respect to the segmenting principle (which advises multimedia designers to chunk their materials and allow users to control pacing), Mayer's research suggested that its effects may not be as strong when the material is simple, when the material is slow paced, or when learners are experienced with the material.

Although each principle has its own set of these conditions (which we encourage you to read about in Mayer's book if you're interested), there is at least one high-level qualification that's worth mentioning. Mayer proposes an overarching **individual differences principle**, which suggests that "certain of the twelve design principles reviewed in this book may help low-experience learners but not help high-experience learners" (pp. 271–272). This speaks strongly to the role of prior knowledge in multimedia learning—indeed, in learning overall. Mayer argues, in fact, "prior knowledge is the single most important individual difference dimension in instructional design. If you could know just one thing about a learner, you would want to know the learner's prior knowledge in the domain" (p. 193).

Although generally Mayer's experiments involved asynchronously produced multimedia presentations (that is, there were no live lectures), they were presented across a variety of media. Accordingly, he believes these principles embody best practices across a variety of media:

The cognitive theory of multimedia learning is based on a knowledge-construction view in which learners actively build mental representations in an attempt to make sense out of their experiences. Instead of asking which medium makes the best deliveries, we might ask which instructional techniques help guide the learner's cognitive processing of the presented material. (p. 231)

With these conditions in mind, it's important to sum up the conditions that make up the cognitive theory of multimedia learning:

- The principles apply to low-knowledge learners.
- The principles apply to multimedia messages that describe processes.
- The principles are medium agnostic.

Mayer's overarching thesis—that people learn better when you use pictures and words together—may be intuitive to many instructors. What may be less intuitive, however, is how to maximise the efficacy of multimedia messages based on the specifics of how humans process information during learning. Mayer's theories are a rejection of multimedia learning as **knowledge transmission** (transplanting information from instructor to learner) and **response strengthening** (promoting recall through drill and practice methods). Instead, the theory embraces a **knowledge construction** perspective: "that multimedia learning is a sense-making activity in which the learner seeks to build a coherent mental representation from the presented material" (p. 17).

It is important:

- When it comes to learning, the human mind is a dual-channel, limited-capacity, active-processing system.
- Instructors should manage their learners' essential processing, optimise their generative processing, and minimise their extraneous processing through thoughtful construction of multimedia presentations.
- These principles are most applicable when the multimedia messages describe processes and when learners are inexperienced.

Clearly, Mayer's multimedia principles provide quite a few guidelines for the design of multimedia presentations.

The Mayer's multimedia principles are summarised in a table (2 pages):

https://ctl.wiley.com/wp-content/uploads/2016/07/MultimediaPrinciples_Summary.pdf

Mayer's theory aligns with contemporary thinking on effective learning, which embraces a constructivist perspective: Students learn most effectively when they have to construct their own knowledge structures and mental models. As Mayer tells us, "instructional design involves not just presenting information, but also presenting it in a way that encourages learners to engage in appropriate cognitive processing" (p. 168). By following the principles of the cognitive theory of multimedia learning, instructors can help ensure that their multimedia presentations will enhance student learning.

6. Bloom's Taxonomy for Creating Learning Exercises

Designing effective and interactive tasks requires careful consideration of various factors, including the principles of multimedia design and Bloom's taxonomy of educational objectives. Since the Bebras tasks are designed for assessing specific knowledge and skills, it is important to decide the difficulty level of the tasks and categorise them accordingly. To do this, first we should understand the cognitive domain of Bloom's taxonomy for creating interactive tasks since we need to determine the cognitive level according to the Bloom Taxonomy. The original taxonomy (1956) has six levels (Armstrong, 2010).

- Knowledge "involves the recall of specifics and universals, the recall of methods and processes, or the recall of a pattern, structure, or setting."
- Comprehension "refers to a type of understanding or apprehension such that the individual knows what is being communicated and can make use of the material or idea being communicated without necessarily relating it to other material or seeing its fullest implications."
- Application refers to the "use of abstractions in particular and concrete situations."

- Analysis represents the "breakdown of a communication into its constituent elements or parts such that the relative hierarchy of ideas is made clear and/or the relations between ideas expressed are made explicit."
- Synthesis involves the "putting together of elements and parts so as to form a whole."
- Evaluation engenders "judgments about the value of material and methods for given purposes."

Then this taxonomy was revisited and revised by a group of scientists in 2001, and used "action words" as categories to describe the cognitive processes by which thinkers encounter and work with knowledge as including remembering, understanding, applying, analysing, evaluating, and creating.

Before providing examples first let us give definitions, sample verbs and also add knowledge types again with explanations: factual, conceptual, procedural and meta-cognitive https://cft.vanderbilt.edu/guides-sub-pages/blooms-taxonomy/#2001

Here are some examples of interactive tasks at each cognitive level:

Remembering: Create a quiz or flashcards to help learners memorise key terms or concepts.

Understanding: Design a scenario-based activity where learners need to apply their understanding of a concept to solve a problem.

Applying: Create a simulation or game where learners need to apply their knowledge to complete a task or achieve a goal.

Analysing: Design a case study or scenario where learners need to analyse a situation and identify the key issues or problems.

Evaluating: Create a debate or discussion activity where learners need to evaluate different perspectives or arguments.

Creating: Design a project or assignment where learners need to create something new using their knowledge and skills.

By following these steps, you can create interactive tasks that engage learners at different cognitive levels and help them achieve their learning objectives.

7. Computer Science Concepts and Computational Thinking Skills

Bebras tasks should be logical and grounded in computer science concepts. Here are some ideas for Bebras-style short tasks that could be used for computer science education.

7.1. Algorithmic Thinking

Algorithmic Thinking provide students with a set of instructions that represent a specific task or problem, and asks them to analyse and improve the algorithm used to solve it.

This form of thinking involves the ability to decompose a complex problem into a series of simple steps or instructions, organised in a logical and orderly manner, to solve it effectively and efficiently. In other words, algorithmic thinking is the ability to design and create algorithms.

An algorithm is a set of precise and ordered instructions used to perform a task or solve a specific problem. These instructions are usually sequential and must follow a particular order, and may also include conditions, loops and other programming elements.

Algorithmic thinking is applied in many areas of life, not just programming. For example, when planning a party, algorithmic thinking can be used to break down tasks into simple, organised steps, such as sending invitations, buying food and drink, decorating the space, and preparing the music. In this way, you can ensure that all aspects of the party are covered and are carried out effectively and efficiently.

In the context of programming, algorithmic thinking is a fundamental skill for designing and creating software. A programmer must be able to break down a problem into logical and orderly steps, design an effective and efficient algorithm to solve it, and then implement that algorithm in a specific programming language.

In short, algorithmic thinking is a fundamental skill in programming and in many other aspects of life. It is the ability to decompose a complex problem into simple and ordered steps, design an effective and efficient algorithm to solve it, and then implement that algorithm in a specific language.

Within the Algorithmic Thinking skill, it is interesting to define these two concepts:

Modelling

This is about establishing the steps to be followed to solve the problem until the solution is reached. Modelling is often done by creating mathematical models or simulations that allow exploring different scenarios and evaluating possible solutions.

Automation

This is about doing repetitive or tedious tasks with or like a computer, in order to save labor and time, thus being more efficient.
Both problem modelling and task automation are essential components of Algorithmic Thinking, as they help decisively in the design of the problem solving process, allowing repetitive and tedious tasks to be carried out effectively, thus saving time and reducing errors.

Examples of Algorithmic Thinking

1. The steps or instructions to follow to assemble an IKEA piece of furniture.

2. The steps to follow to make a cooking recipe.

3. Any task performed by a robot or a calculator.

4. Suppose you work for a courier company and are trying to optimise package delivery routes to reduce costs and improve efficiency. To model this problem, you could follow the steps below:

a. Problem identification: this is the planning of delivery routes for a set of destinations in a given geographic area. The objectives are to minimise fuel costs and reduce delivery time, while respecting time and capacity constraints.

b. Abstraction and simplification: to represent this problem in mathematical or simulation terms, different abstractions and simplifications could be used. One possible approach is to represent each destination as a node in a graph, where the edges represent the possible routes between destinations. Optimization algorithms could then be used to find the shortest route connecting all destinations, minimising the total distance travelled and considering time and capacity constraints.

c. Validation and verification: Once the model is created, its accuracy and usefulness could be validated by simulating different scenarios and comparing the results obtained with real routes. Adjustments and improvements could also be made to the model as needed.

In summary, modelling and automating a real problem, such as packet delivery routes, allows the problem to be addressed in a more efficient and scalable manner, through the use of mathematical tools and optimization algorithms. This can significantly improve efficiency and reduce costs for the courier company, which is a clear example of how Algorithmic Thinking can be applied to real-world problems.

Algorithmic thinking also involves elements of logic or computational logics. Logics present students with a set of logical statements or a logical problem, and ask them to use their reasoning skills to determine the correct outcome or solution.

Logic helps us to establish and check facts, and make predictions. For example, completing logic puzzles such as Sudoku requires us to reason about which number to place in each square.

7.2. Data collection, Analyses, and Representation

Data provides students with a set of data and asks them to organise it using a specific data structure, such as a linked list or a binary tree. This can help them understand the different types of data structures and how they can be used.

This skill allows us to better understand the problem we are trying to solve. Data collection and analysis involves knowing how to distinguish what is important from what is not so important; knowing how to process, organise and examine this data to identify key patterns, trends and relationships.

Data analysis includes the Pattern Recognition.

Data analysis also allows you to evaluate the effectiveness of proposed solutions and adjust your approach accordingly. In general, data collection and analysis provide a solid, empirical basis for informed decision making and effective problem solving.

Data representation can be graphical or numerical, and helps us visualise patterns and trends in the data that may not otherwise be evident.

For example, by representing data in a line or bar chart, we can identify trends and patterns in the data and, from there, make hypotheses and draw conclusions about what might be causing those patterns. These hypotheses and conclusions can help identify possible solutions or approaches to solving the problem.

In addition, data representation also serves to communicate complex information in a clear and concise manner to others involved in solving the problem. By presenting data in a clear and easy-to-understand form, everyone involved is more likely to have a common understanding of the problem and possible solutions.

Examples of Data Collection, Analysis and Representation

1. To collect in a table the data corresponding to the evolution of the population of a place over the years.

2. To represent a given function by means of a graph.

3. Deduce the climate in a given region from rainfall data collected in a table.

4. Give students a set of data or a pattern and ask them to identify the underlying rule or pattern. This can help develop their problem-solving and analytical skills.

Patterns

To speak of patterns is to speak of regularities. Regularities are everywhere and being able to find them is an essential skill.

A pattern is a succession of elements (auditory, gestural, graphic...) that is built following a rule. This rule can be classified as of repetition or of recurrence.

Just by looking around you can find sets of elements that are arranged in a certain way, following a rule.

Usually, we can find the following two forms of patterns:

1. Repetition patterns:

These are those in which different elements are presented in a periodic fashion.

Different repeating patterns can be created taking into account their structure.

2. Recurrence patterns

These are those in which the regularity with which the elements are presented changes and their rule of formation has to be inferred from them, that is, you can find out what the next element will be by observing the behaviour of the previous ones.

7.3. Decomposition

Decomposition is a CT skill that involves breaking down a complex problem into smaller, more manageable tasks. By decomposing a problem, key patterns and relationships can be identified, and a deeper understanding of the overall problem can be developed. This facilitates the problem-solving process, as each smaller task can be addressed more effectively, leading to a more efficient overall solution.

Decomposition involves thinking of problems as being made up of parts and components. Each part should be able to be understood, solved, developed and evaluated separately.

Examples of Decomposition

1. Preparing a menu in a restaurant involves preparing various dishes independently.

2. They work on an assembly line in a factory.

3. The resolution of mathematical problems must be carried out, in general, by decomposing the whole into tasks that are related to each other, but which admit independent treatment.

7.4. Abstraction

The most important and highest level process in computational thinking is Abstraction. Abstraction provides students with a complex problem and ask them to break it down into smaller, more manageable components. This can help develop their ability to think abstractly and solve complex problems.

The idea behind abstraction is related to reducing the complexity in order to define the main objective(s) (ideas), making the task more understandable by reducing unnecessary details or hiding some of them. This idea can lead us to focus on the relevant data, discarding information that is not essential to obtain the result, or to identify the procedure to be followed to reach that objective.

In the context of computational thinking, abstraction is essential and implies the ability to identify patterns, define problems and represent solutions.

In particular, abstraction has been defined in different ways, such as:

- The process of representing a problem.

- Reducing the complex to define the main objective(s) (ideas).

- The process of making the task more understandable by reducing unnecessary details or hiding some of them.

- The skill in choosing the detail to eliminate or hide, so that the problem becomes easier, without losing everything that is important. Sometimes it is a matter of isolating some specific detail to reflect on it.

The levels of acquisition of Abstraction will be determined by the percentage of objectives and main ideas that are identified, the percentage of unnecessary details that are eliminated, as well as by the formulation of the problem to be solved. It should be remembered that "abstraction hides details from the view of the system, but not from the system". This implies that details are virtually eliminated to get to that main idea, but then you have to work with them to solve the problem.

Examples of abstraction

1. To analyse the free fall motion of an object we have to disregard elements such as temperature, air density, etc., staying only with the fundamental elements: height, weight of the object, etc.

2. When drawing a city map, we focus on the fundamental elements (streets, buildings), which we represent schematically, and we eliminate all the accessories (cars, urban furniture, real appearance of the buildings).

3. Sometimes we consider certain parts as black boxes that we assume to work and we do not go into the functioning of them. For example, in mathematics, when a problem appears the sine of a certain value and we resort to a calculator, we do not go into the details of how the calculation of that value is performed.

4. Decide to represent the elements of a city (sidewalks, roads, houses, stores, schools, health centres, etc.) through certain symbology when making a map of the city.

5. Represent by means of a system of equations a mathematical problem (or physical, or related to economics).

7.5. Generalisation (Transferability)

Generalisation (or Transferability) is an important concept in computational thinking that refers to the ability to extrapolate patterns and relationships from data, and apply them to new or unfamiliar situations. In other words, it involves the ability to deduce a general rule from a set of specific examples.

It is the process of formulating generic concepts through the extraction of common qualities and connections, identifying patterns or from specific examples.

It is a way of solving new problems on the basis of solutions to previous problems or previous experience.

Examples of Generalization

1. Conduct the study of 4 types of trees and deduce the essential properties that characterise them and lead to the concept of tree: 1 trunk that branches at a certain height from the ground, etc.

2. Induction Method. We create models of concepts by generalising simple examples. We look for common patterns that explain the examples. We obtain general conclusions from specific information.

3. Analogical or deductive learning. We apply deduction to obtain general descriptions from an example of a concept and its explanation. It is based on mathematical logic.

7.6. Evaluation and Adjustment

Evaluation involves the ability to assess and analyse the effectiveness of an algorithm, model or solution for a given problem, while adjust refers to the ability to modify and improve an algorithm, model or solution to increase its effectiveness.

In programming, evaluation and adjustment are also important skills for creating effective and efficient solutions. After writing a code, it is necessary to test it and evaluate its effectiveness by identifying errors, bugs (debugging) or limitations. Once identified, it is possible to adjust the code to improve its performance, make it more modular and reusable, or increase its efficiency.

We could define it as the ability to make judgments objectively and systematically whenever possible; to correct by systematically applying analysis and evaluation skills, using logical thinking and reflection to predict and verify results.

Examples of Evaluation and Adjustment:

1. Once a problem has been solved, check that it makes sense of the result obtained. For example, if when calculating the area of a certain region the result obtained is a negative number, we know that an error has been made.

2. When we write a text to send to someone else, we must reread it (even more than once), to make sure that the content fits what we wanted to tell, and that, from a formal point of view, it has no spelling or syntax mistakes.

3. If a group of students is working on the resolution of a task and several options are proposed, it is interesting to know how to evaluate the pros and cons of each one in order to choose the best one.

8. Examples: Analysing Interactive Bebras Tasks

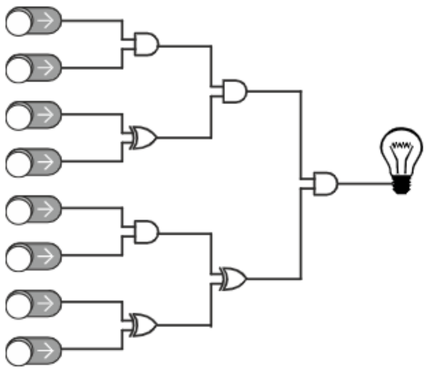
We have selected several interactive Bebras tasks and perform their analysis by applying Mayer's principles and Bloom's taxonomy.

Example 1

2022-AU-03, Lights On

ID and name of the Bebras task	Mayer's multimedia Principles addressed (M1-M7)	Difficulty level according to Bloom's taxonomy (B1-B6)	Interactivity type relevant for the task
2022-AU-03, Lights On	M1, M2, M3, M4, M7	B3	Click-On-Object

The game "Light on" has 8 switches that can be operated. Wires lead out of these switches, which lead through some components and finally to a light bulb.



The output from the component  *is ON only when BOTH incoming wires are ON.*

The output from the component  *is ON when exactly ONE of the incoming wires is ON.*

Question / Challenge

Which switches have to be ON to switch on the light at the end?

Answer Options / Interactivity Description

Interactive: an image of the 8 buttons and the wires coming out, leading into 4 Logic Gates, that lead into 2 squares/triangles, and into the final triangle and then the light bulb.
The 8 buttons start in their default off state, which looks like an unpressed button that is unlit . When clicking on a button it becomes 'pressed' 

Clicking again turns the button OFF, returning it to the first state.

M1: Image principle. The image is integrated into the task.
M2: Signalling principle. The image is interactive, students can press buttons and observe the result (light on or off).

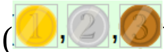
M3: Redundancy principle. The task starts with a very short introduction, which only encourages the student to explore the situation.
M4: Spatial contiguity principle. The task is solved using the same interactive image. The student can always set the initial image.
M7: Multimedia principle. Text and interactive image support each other.

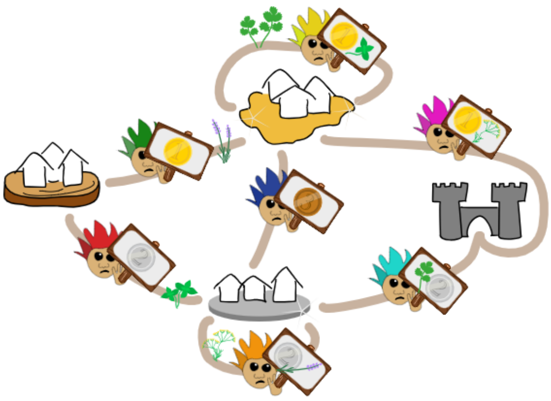
B3: Applying. In this problem, students apply their knowledge of computational thinking (Boolean Data, AND gate, XOR gate; Boolean Logic), which is the basis of computers (transistors) and is widely used in programming.

Example 2

2022-CH-04, Greedy Trolls

ID and name of the Bebras task	Mayer's multimedia Principles addressed (M1-M7)	Difficulty level according to Bloom's taxonomy (B1-B6)	Interactivity type relevant for the task
2022-CH-04, Greedy Trolls	M1, M2, M3, M4, M7	B5	Drag & Drop

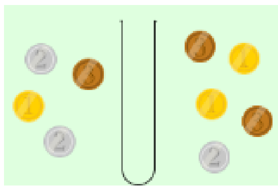
Charlie wants to go from his home village to the castle, but in the woods between the villages are greedy trolls waiting on the paths. All of them request one specific coin () from anybody who passes. Some of them also want one specific herb () as an extra token. Luckily those herbs can be found in the woods on the paths between some of the villages. In the picture you can see which coin each troll wants and if they also require a herb. It's not possible to gather a herb without first paying the troll on that path.



Charlie has a tube to store his coins. He fills it before leaving. Because he can only access one coin after the other, he must fill his tube in the exact order in which he needs the coins. Charlie also travels with a small backpack to store the herbs he finds in the woods. The backpack is very narrow; therefore, he can only access the top-most herb in his backpack. Charlie leaves with an empty backpack.

Question / Challenge

Fill Charlie's tube with five coins in the right order, so that he can pay the greedy trolls on his way to the castle. Don't forget about the herbs he must collect.



Answer Options / Interactivity Description

There should be a tube the width of a coin and the height of five coins. As well as one symbol each for a gold, silver and copper coin. From the symbols it should be possible to drag the corresponding coin to the tube.

M1: Image principle. The task images (central, auxiliary and solution interactive) show only the required objects and their arrangement.
M2: Signalling principle. The key clues in the text and the figure are closely linked to this complex task.
M3: Redundancy principle. All textual information is linked to the images. You cannot read and comprehend without a picture, or vice versa: understanding the text requires close study of the pictures. The text and the pictures are understood by examining them in parallel.
M4: Spatial contiguity principle. The challenge is complex, and depending on the size of the screen, the interactive coin toss into the tube may not fit on a single screen.
M7: Multimedia principle. This task requires not only a coherent image, but also the highlighting of its details (coins and herbs). These details are further embedded in the text.

B5: Evaluating. Students apply the important stack concept (data structure) of computational thinking and evaluate two possible solution paths that lead to the same final result.

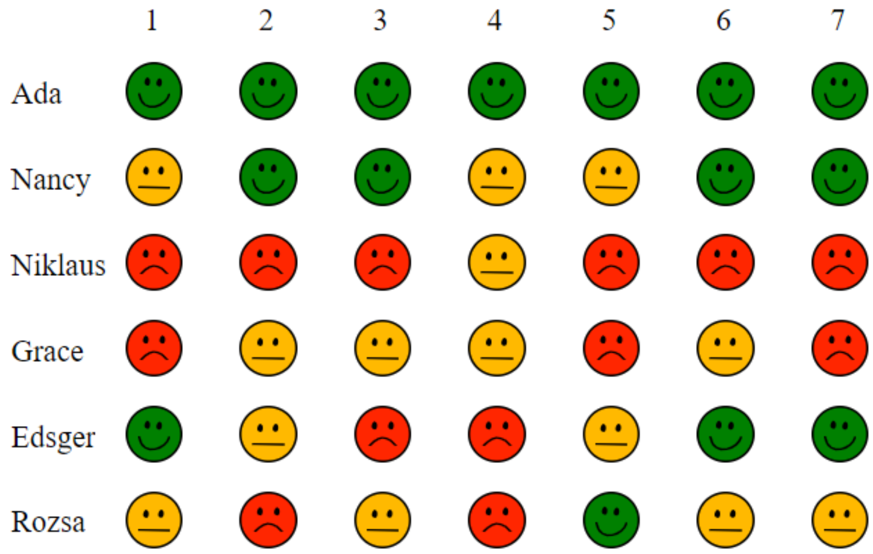
Example 3

2022-DE-07, Favorite Movie

ID and name of the Bebras task	Mayer's multimedia Principles addressed (M1-M7)	Difficulty level according to Bloom's taxonomy (B1-B6)	Interactivity type relevant for the task
2022-DE-07, Favorite Movie	M1, M2, M3, M4, M7	B6	Click-To-Change

A group of friends want to watch a movie together. Each person rates each of seven movies with

best  , medium  or bad . See table:



A movie is a "favourite" if each person has given it their own best rating. For example, movie 1 is not a favourite because Niklaus gave his best rating to movie 4. Unfortunately, there is no favourite movie now. Then Ada wants to convince as few friends as possible to change their rating so that there is a favourite movie after all.

Question / Challenge

Help Ada and others to change as few ratings as possible so that there is a favourite movie.

Answer Options / Interactivity Description

The author would prefer an interactive version, where contestants can actively change ratings as needed.

M1: Image principle. The main picture is very simple: it is made up of ordinary details (names, 3 types of icons), although the amount of information in this picture is considerable.
M2: Signalling principle. The rating icons explain the whole central image.
M3: Redundancy principle. The task shall not contain the slightest unnecessary detail. The text and images are integrated with each other.
M4: Spatial contiguity principle. The design of the task is very compact. The interactive picture of the task situation overlaps with the solution picture.
M7: Multimedia principle. The text and graphics support each other. The main image is interactive. It is both an explanation of the problem situation and an interactive solution.

B6: Creating: This task requires students to have excellent skills in analysing a problem and devising a strategy to solve it. Here, students' general skills converge with computer science.

9. Recommendations for Creating Interactive Bebras Tasks

By using exercises that are logical and grounded in CS concepts, students can develop their CT and problem-solving skills, as well as gain a deeper understanding of the underlying principles of computer science.

Bebras tasks are a set of challenges that aim to develop computational thinking and problem-solving skills in students. To analyse these tasks using Bloom's taxonomy, we need to understand the different levels of cognitive skills and knowledge as defined by Bloom's taxonomy.

Summarising, a framework for creating interactive tasks that incorporates both Bloom's Taxonomy and Mayer's Multimedia Design Principles aligned with CS concepts and CT skills considering appropriate interaction type are elaborated and described below.

Bloom's taxonomy classifies cognitive skills and knowledge into six hierarchical levels: remembering, understanding, applying, analysing, evaluating, and creating. Each level is progressively more complex and builds upon the previous level.

Let's look at how Bebras tasks can be categorised according to Bloom's taxonomy:

B1: Remembering: The tasks at this level require students to recall basic facts, concepts, or procedures related to computational thinking. For example, a task may ask students to identify the basic components of an algorithm or define a programming term.

B2: Understanding: Tasks at this level require students to demonstrate comprehension of a concept or idea related to computational thinking. For example, a task may ask students to explain how an algorithm works or how a programming language syntax is structured.

B3: Applying: Tasks at this level require students to use their knowledge of computational thinking to solve problems or perform tasks. For example, a task may ask students to write a code snippet to solve a given problem or to identify the most efficient algorithm to solve a particular task.

B4: Analysing: Tasks at this level require students to break down complex problems into smaller parts and analyse the relationships between them. For example, a task may ask students to identify the steps in an algorithm that can be optimised to reduce execution time or to analyse a given code snippet for possible errors.

B5: Evaluating: Tasks at this level require students to make judgments and assess the effectiveness of different approaches or solutions. For example, a task may ask students to evaluate the efficiency of different algorithms for a particular task or to analyse the pros and cons of different programming languages for a particular project.

B6: Creating: Tasks at this level require students to use their knowledge and skills to generate new ideas, products, or solutions. For example, a task may ask students to design a new algorithm to solve a specific problem or to create a new software application that solves a real-world problem.

Bebras tasks can be categorised into different levels of cognitive skills and knowledge as defined by Bloom's taxonomy. By using Bloom's taxonomy to analyse these tasks, we can ensure that students are challenged at the appropriate level and are developing the necessary skills to become proficient in computational thinking and problem-solving.

We will consider Mayer's multimedia principles as a set of guidelines for designing effective interactive multimedia tasks. While Bebras-like tasks may be short and concise, the principles can still be applied to create more effective and engaging tasks. After careful consideration, it is decided that out of 12, 7 of these multimedia principles can be applied to any of the Bebras tasks. Here are these principles and reflections for Bebras tasks.

M1: Image principle: This principle suggests usage of meaningful, relevant graphics that contribute to the understanding of the content. Thus, use of meaningful and explanatory graphics is strongly encouraged for any of Bebras tasks.

M2: Signalling principle: This principle suggests that cues or signals should be used to highlight important information, and to help learners understand the structure of the task. All Bebras tasks are based on a case or scenario, thus they will always have clues in them.

M3: Redundancy principle: This principle suggests that multimedia learning materials should not contain redundant information, as this can lead to cognitive overload. Bebras tasks are always intended to be short and contain clear messages.

M4: Spatial contiguity principle: This principle suggests that multimedia learning materials should present related information in close proximity to each other, to help learners integrate the information more easily. This is about the design of the Bebras tasks on the screen or on the page, so the content should be kept close and related to each other.

M5: Segmenting principle: The segmenting principle suggests that complex material should be broken down into smaller, manageable segments to facilitate learning. Bebras tasks are already segmented. Each task starts with a case or scenario, continues with the problem definition or situation, and ends with the question.

M6: Personalization principle: This principle suggests that multimedia learning materials should be designed to support learners' individual differences and preferences. This is about the use of conversational style within the text of Bebras tasks that makes the tasks easily understandable when compared with the formal style.

M7: Multimedia principle: This principle suggests that the use of multimedia, including text, images, and audio, can improve learning outcomes by providing multiple channels for presenting information. All Bebras tasks are encouraged to include text and graphics.

By applying these principles to Bebras tasks, designers can ensure that the tasks are effective and engaging, even if they are short and concise. For example, designers could use cues or signals to highlight important information in the task, eliminate redundant information to prevent cognitive overload, and use multimedia elements to present information in multiple formats. The principles can be adapted and applied to suit the needs of the specific task and the target audience, while still ensuring that the task is effective and engaging.

Hence, any Bebras task creator should be aware of that he/she should:

1. Try to address as many multimedia principles as possible
2. Decide the difficulty level according to Bloom's taxonomy
3. Select best interactivity type relevant for the question

Below we have provided a template with both the Mayer's Multimedia Design Principles and the Bloom's Taxonomy. Allocation of the Bebras interactive tasks from 2021-2022 is presented in Appendix 2.

ID and name of the Bebras task	Mayer's multimedia Principles addressed (M1-M7)	Difficulty level according to Bloom's taxonomy (B1-B6)	Interactivity type relevant for the task
Bebras task 1			
Bebras task 2			
Bebras task 3			

As a summary, the Following steps can be considered as a general start to the process.

1. **Identify the learning objective**: Start by identifying the learning objective that you want to achieve through the interactive task. This will help you determine the type of interaction you need to create and the level of cognitive engagement required. Which computer science concept and CT skill do you want to address?

2. **Determine the level of Bloom's Taxonomy**: Once you have identified the learning objective, determine the appropriate level of Bloom's Taxonomy for the task. Keep in mind that difficulty level can change according to age. What is the difficulty level of this Bebras task according to [age level]?

3. **Choose the appropriate multimedia elements**: Based on the learning objective and the level of Bloom's Taxonomy, choose the appropriate multimedia elements to use in the task. Mayer's Multimedia Design Principles suggest using relevant and meaningful visuals, concise and coherent text, and appropriate audio or narration. What will be the narration of the Bebras task? What kind of graphics will be used to support the task content?

4. **Design the interaction**: Design the interaction based on the multimedia elements chosen. The interaction should engage the user and help them achieve the learning objective. Examples of interactive tasks include quizzes, drag and drop activities, matching exercises, and simulations. Which type of interaction best meets your expectations?

5. **Incorporate feedback**: Provide feedback to the user after they complete the interactive task. Feedback can help reinforce learning and correct any misconceptions. Mayer's Multimedia Design Principles suggest that feedback should be immediate, informative, and specific. What kind of feedback will be provided to the student based on the correctness of his7her answer?

6. **Evaluate the effectiveness**: Finally, evaluate the effectiveness and efficiency of the interactive Bebras task in achieving the learning objective. This can be done through user testing or by analysing the learning outcomes of the task. For evaluating the whole effort, a rubric could be useful. To what extent the criteria provided within the “Framework for Creating Interactive Bebras Tasks” has been met?

Assessment Rubric for the Framework for Creating Interactive Tasks

Criteria	Excellent	Acceptable	Needs Improvement	Points
Identification of the learning objective	Learning objective is effectively defined that students are expected to achieve through the interactive task (10-15 points)	Learning objective is poorly defined that students are expected to achieve through the interactive task (6-10 points)	Learning objective is not clear and needs improvement that students are expected to achieve through the interactive task (0-6 points)	___ points
Appropriateness level of difficulty level according to Bloom’s taxonomy (B1-B6)	Difficulty level addressed according to age groups are relevant (10-15 points)	Difficulty level addressed according to age groups may show variety (6-10 points)	Difficulty level needs to be reconsidered to address appropriate difficulty level (0-6 points)	___ points
The Number of Mayer’s Multimedia Principles addressed (M1-M7)	More than 5 of the principles are considered in the design of the task (10-15 points)	Between 3- 5 of the principles are considered in the design of the task (6-10 points)	Less than 3 of the principles are considered in the design of the task (0-6 points)	___ points
Appropriateness of the interactivity type applied to the task	Selected interactivity type engages the user and help them achieve the learning objective	Some other interactivity types can be more relevant for the task in terms of engagement	Another interactivity type should be considered for the task	___ points

	(10-15 points)	(6-10 points)	(0-6 points)	
Usefulness of the feedback provided	Provided feedback has the potential to reinforce learning and correct any misconceptions (10-15 points)	Provided feedback has limited potential to reinforce learning and correct any misconceptions (6-10 points)	Provided feedback needs to be improved according to true and false answers (0-6 points)	___ points
General Evaluation	Question can be considered as high quality (8-10 points)	Question can be considered as good quality (5-8 points)	Question can be considered as poor quality (0-5 points)	___ points
Total Points	68-100 points	41-68 points	0-41points	___ /100 points

By following this framework, we can create effective and engaging interactive tasks that incorporate both the principles of multimedia design and Bloom's Taxonomy. The assessment rubric will not be used for evaluation but also could serve as a guide while preparing the task.

References

Armstrong, P. (2010). Bloom’s Taxonomy. Vanderbilt University Center for Teaching. Retrieved [todaysdate] from https://cft.vanderbilt.edu/guides-sub-pages/blooms-taxonomy/.

Bebras International Challenge on Informatics and Computational Thinking: www.bebras.org.

Bebras Community Statutes: www.bebras.org/sites/default/files/BebrasStatutes_rc3.pdf

Bocconi, S., Chioccariello, A., Kampylis, P., Dagienė, V., Wastiau, P., Engelhardt, K., Earp, J., Horvath, M.A., Jasutė, E., Malagoli, C., Masiulionytė-Dagienė, V. and Stupurienė, G. (2022). *Reviewing Computational Thinking in Compulsory Education*. Inamorato Dos Santos, A., Cachia, R., Giannoutsou, N. and Punie, Y. editor(s), Publications Office of the European Union, Luxembourg, doi:10.2760/126955, JRC128347.

Bowers, D., Petre, M., & Howson, O. (2019, November). Aligning Competence Hierarchies with Bloom's Taxonomies: Changing the focus for computing education. In *Proceedings of the 19th Koli Calling International Conference on Computing Education Research* (pp. 1-2).

Boyle, T. (2003). Design principles for authoring dynamic, reusable learning objects. *Australasian Journal of Educational Technology*, *19*(1).

Butcher, K. R. (2014). The multimedia principle. *The Cambridge handbook of multimedia learning*, *2*, 174-205.

Dagiene, V., Futschek, G., Stupuriene, G. (2019). Creativity in Solving Short Tasks for Learning Computational Thinking. *Constr. Found*., 14, 382–396.

Dagienė, V., Hromkovic J., & Lacher R. (2020). A Two-Dimensional Classification Model for the Bebras Tasks on Informatics Based Simultaneously on Subfields and Competencies. *Lecture Notes in Computer Science*, 12518, 42-54, https://doi.org/10.1007/978-3-030-63212-0_4.

DeBell, A. How to use Mayer's 12 Principles of Multimedia [Examples included]: https://waterbearlearning.com/mayers-principles-multimedia-learning/

Conklin, J. (2005). A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives complete edition.

Fletcher, J. D., & Tobias, S. (2005). The multimedia principle. *The Cambridge handbook of multimedia learning*, *117*, 133.

Greer, D. L., Crutchfield, S. A., & Woods, K. L. (2013). Cognitive theory of multimedia learning, instructional design principles, and students with learning disabilities in computer-based and online learning environments. *Journal of Education*, *193*(2), 41-50.

Huitt, W. (2011). Bloom et al.'s taxonomy of the cognitive domain. *Educational psychology interactive*, *22*, 1-4.

Issa, N., Schuller, M., Santacaterina, S., Shapiro, M., Wang, E., Mayer, R. E., & DaRosa, D. A. (2011). Applying multimedia design principles enhances learning in medical education. *Medical education*, 45(8), 818-826.

ISTE&CSTA (International Society for Technology in Education (ISTE) and the Computer Science Teachers Association (CSTA)). Operational definition of computational thinking for K-12 education, 2011.

Krathwohl, D. R. (2002). A revision of Bloom's taxonomy: An overview. *Theory into practice*, *41*(4), 212-218.

Krüger, J. M., & Bodemer, D. (2022). Application and investigation of multimedia design principles in augmented reality learning environments. *Information*, *13*(2), 74.

Mahajan, R., Gupta, K., Gupta, P., Kukreja, S., & Singh, T. (2020). Multimedia instructional design principles: Moving from theoretical rationale to practical applications. *Indian pediatrics*, *57*, 555-560.

Masapanta-Carrión, S., & Velázquez-Iturbide, J. Á. (2018, February). A systematic review of the use of bloom's taxonomy in computer science education. In *Proceedings of the 49th acm technical symposium on computer science education* (pp. 441-446).

Mayer, R. E., & Moreno, R. (1998). A cognitive theory of multimedia learning: Implications for design principles. *Journal of educational psychology*, *91*(2), 358-368.

Mayer, R. E. (2017). Using multimedia for e-learning. *Journal of computer assisted learning*, *33*(5), 403-423.

Mayer, R. E. (2009).*Multimedia learning* (2nd ed.). Cambridge, England: Cambridge University Press.

Mayer, R. E. (2013). Ten research-based principles of multimedia learning. In *Web-based learning* (pp. 371-390). Routledge.

Moreno, R., & Mayer, R. E. (2000). A learner-centered approach to multimedia explanations: Deriving instructional design principles from cognitive theory. *Interactive multimedia electronic journal of computer-enhanced learning*, *2*(2), 12-20.

Nelson, B., & Kim, Y. (2020). 12 Multimedia Design Principles in Game-Based Learning. *Handbook of game-based learning*, 307.

Noetel, M., Griffith, S., Delaney, O., Harris, N. R., Sanders, T., Parker, P., ... & Lonsdale, C. (2022). Multimedia design for learning: An overview of reviews with meta-meta-analysis. *Review of Educational Research*, *92*(3), 413-454.

Selby, C. C. (2015, November). Relationships: computational thinking, pedagogy of programming, and Bloom's Taxonomy. In *Proceedings of the workshop in primary and secondary computing education* (pp. 80-87).

Starr, C. W., Manaris, B., & Stalvey, R. H. (2008). Bloom's taxonomy revisited: specifying assessable learning objectives in computer science. *ACM Sigcse Bulletin*, *40*(1), 261-265.

Tufan, D. (2021). Multimedia design principles for microlearning. *Microlearning in the digital age: The design and delivery of learning in snippets. Routledge. http://doi.org/10.4324/9780367821623-6.*

University of Groningen. Mayer's Principles of Multimedia Design and Learning: https://www.rug.nl/education/online-teaching/tools/video/diy-video-studio-harmoniegebouw/multimedia-principles.pdf

University of Hartford. 12 principles of Multimedia Learning: https://www.hartford.edu/faculty-staff/faculty/fcld/_files/12%20Principles%20of%20Multimedia%20Learning.pdf

Vaníček, J., Šimandl, V., & Klofáč, P. (2021). A Comparison of Abstraction and Algorithmic Tasks Used in Bebras Challenge. *Informatics in Education*, 20(4), 717-736, https://doi.org/10.15388/infedu.2021.30.

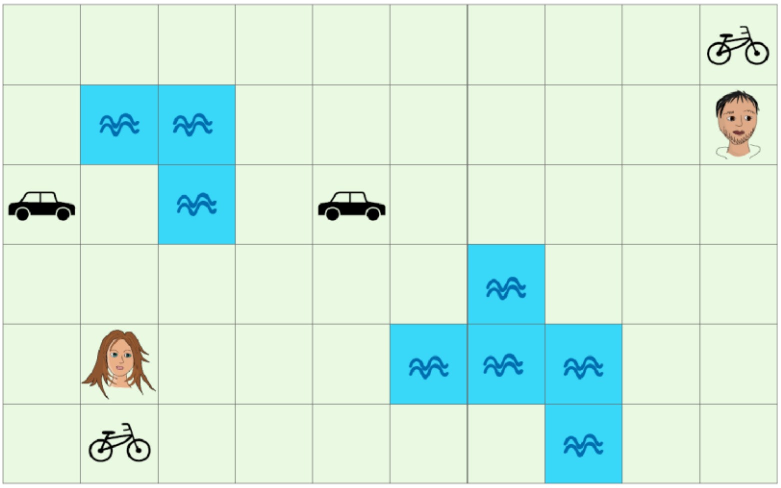
Velázquez-Iturbide, J. Á. (2021, November). An Analysis of the Formal Properties of Bloom's Taxonomy and Its Implications for Computing Education. In *Proceedings of the 21st Koli Calling International Conference on Computing Education Research* (pp. 1-7).

Wiley University. Principles of Multimedia Learning: https://ctl.wiley.com/principles-of-multimedia-learning/

Wing, J. M. (2006). Computational thinking. *Communications of the ACM*, 49(3), 33-35.

1. Meeting race

Two friends need to meet urgently - see the map below. They can walk from a square to a horizontally or vertically adjacent square in exactly one minute. If they reach a bike or car they can use it to travel faster – 2 squares in one minute with a bike, 5 squares with a car.
They cannot travel over water.



Question / Challenge

What is the minimum number of minutes they need to end up on the same square?

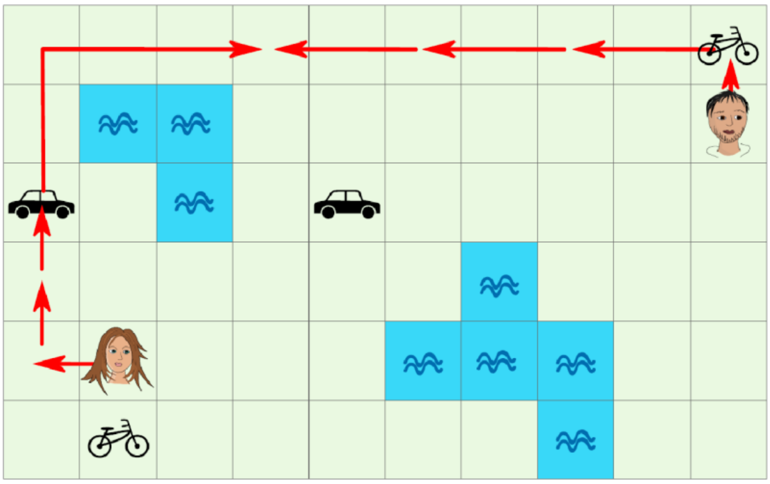
Answer Options / Interactivity Description

Open Integer (minutes).

Optionally some interactivity could be added (e.g., allowing the two characters to be moved around the map with the mouse) to help students to think systematically without using pen and paper or needing to touch the screen.

Answer Explanation

The correct answer is 4. This can be achieved by the route shown below:



(Another option is to take the leftmost bike and cycle to the leftmost car and then continue as above.)

To see why 3 minutes are not sufficient, you can reason as follows.

- Although in 3 minutes you can reach the car on the left, there is no time left to drive it anywhere. And that position cannot be reached in three minutes by the other person.

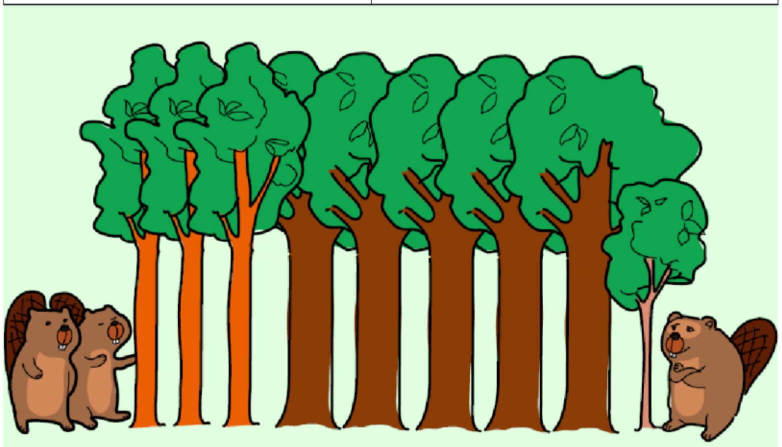
So the cars are of no use and we may as well remove them from the map.

• The two friends are more than 5 minutes away from each other on foot, so they need a bike. In fact, both need a bike because they are separated by more than 9 positions.
But finding that bike costs one minute and with only two minutes left they cannot reach each other, even by bike.

2. Three beavers

Three beavers cut down the trees. Each beaver works on its own. Trees are different thickness and they require different cutting time.

Number of trees of the same thickness	*How many hours is needed for cutting one tree*
5	4
3	3
1	1



The beavers can cut down the trees in any order they want. But they have to finish the current tree they work on, before they start cutting down the next one.

Question / Challenge

What is the least number of hours for the beavers to cut down all trees?

Answer Options / Interactivity Description

Write an integer number

Answer Explanation

Correct answer is 11 hours.

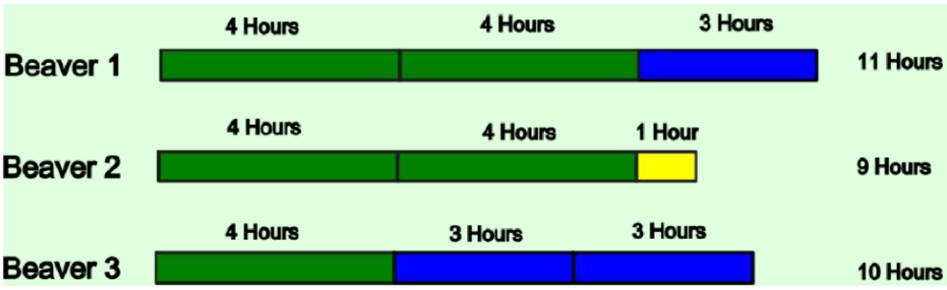
It might appear that the result would be 10 hours.

(5×4+3×3+1×1)/3 = 10

However, you cannot group the trees into three equal groups that allow each beaver to spend ten hours cutting the logs.

As seen in the diagram, the three beavers cannot spend the same time. Two beavers are cutting trees for 11 hours while the third only uses eight hours cutting trees.

We can see it in the next scheme



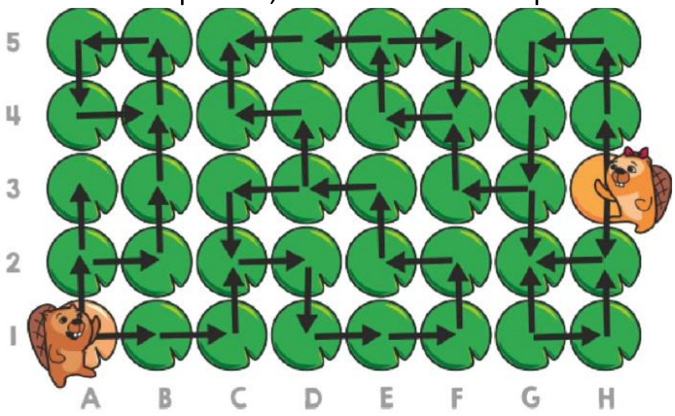
In this scheme, when a beaver finishes cutting a tree, it proceeds to cut the largest tree available.

The three beavers start cutting large trees (4 hours of work) when they finish, simultaneously, the first two start with the last two large trees and the third beaver goes on to cut a medium tree. Since the third beaver finishes earlier, he proceeds to cut a second medium tree. The

first two beavers finish later, simultaneously and choose, one the last medium tree and the other the only small tree. The first beaver spends 11 hours at work, the second nine and the third ten.
In this case, the strategy followed has been to choose the largest tree available to continue the work.

3. Do they meet?

On the lake, beavers can go from one lily pad to another only in the way the arrows show. Bob starts on pad A1, and Nora starts on pad H3.



Question / Challenge

Is it possible that the beavers meet each other? If yes, where may they meet?

Answer Options / Interactivity Description

Interactive task: select the pad/pads where they can meet.

Answer Explanation

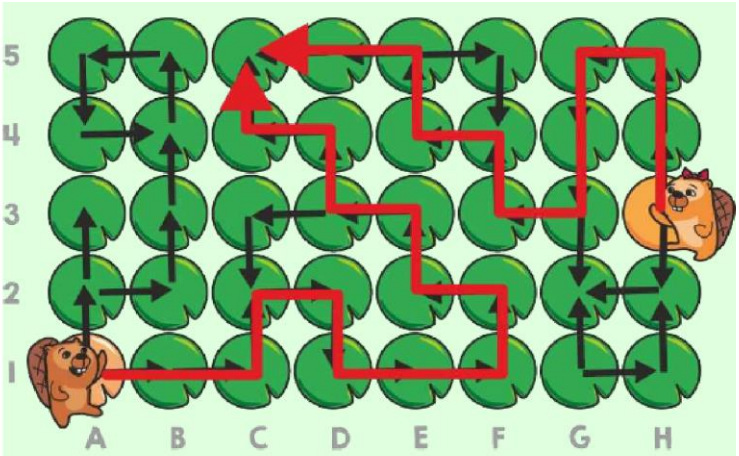
The correct answer is D: The beavers may meet on pad C5.

At his starting position, Bob has two options: If he goes "up", then he may either run into the dead end at A3 or get stuck in the loop that begins at B4. If he goes "right" (to B1), he can continues to D3. At D3 he may either go "left" into a loop that will take him back to D3 eventually or go "up", which makes him end up at C5, another dead end.

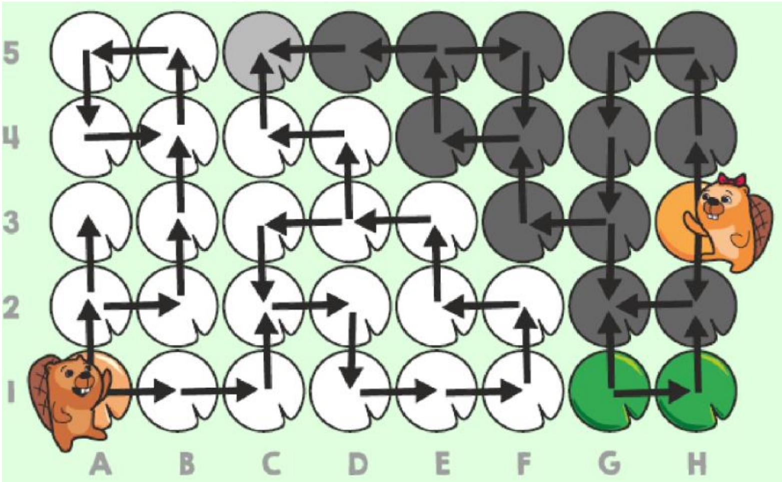
Nora also has two options at the start. If she goes "down", she will run into the dead end at G2. If she goes "up", she will reach G3. From there she may either run into the G2 dead end again, or go "left" and reach E5 eventually. There she may either go into a loop that will take her back to E5 again or reach another dead end at C5.

As we already know, Bob may reach C5 as well, so we can see that they may meet at C5.

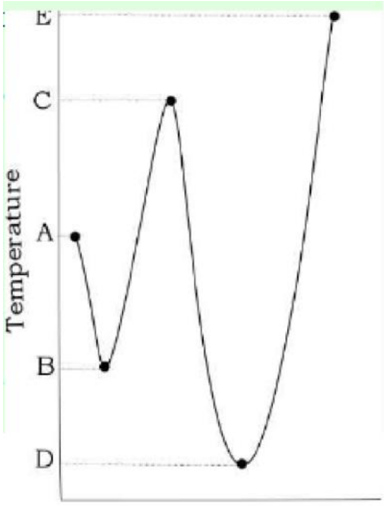
The picture shows the ways along which they both can reach C5.



But this does not yet fully guarantee that they cannot meet at F4 or C5 either. The next picture shows the set of pads that Bob (white) and Nora (dark gray) may reach by following the arrows in any possible way. We can see that C5 is the only pad common to both sets.


5
4
3
2
1
A
B
C
D
E
F
G
H

4. Comfort temperature



Every day beaver Theophilus measures the water temperature and records measurements in a table. He records the first measurement immediately after waking up, and the last one shortly before bedtime. Theophilus knows that the temperature changes constantly, so during the day he records only the extreme temperatures - those before which the temperature increased and then began to decrease, or vice versa – decreased and then began to increase. For example, if the temperature changed as in the drawing, Theophilus would have written the numbers A, B, C, D, E in the table. There is exactly one temperature value, the comfort temperature, at which Theophilus feels best.

Question / Challenge

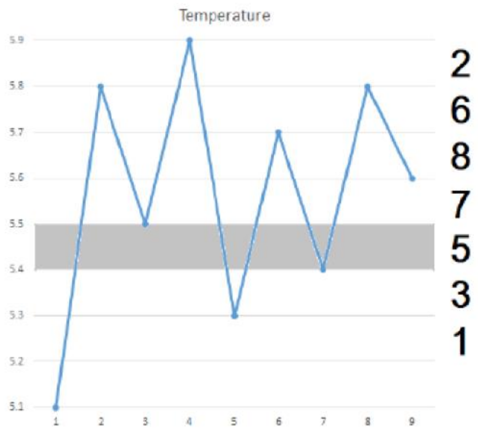
What are the limits of the comfort temperature if the comfort temperature was met exactly five times yesterday and yesterday's observations are the following:
5.1, 5.8, 5.5, 5.9, 5.3, 5.7, 5.4, 5.8, 5.6?

Answer Options / Interactivity Description

Two numbers A and B denoting that comfort temperature is between A and B. Any temperature between 5.4 and 5.5.

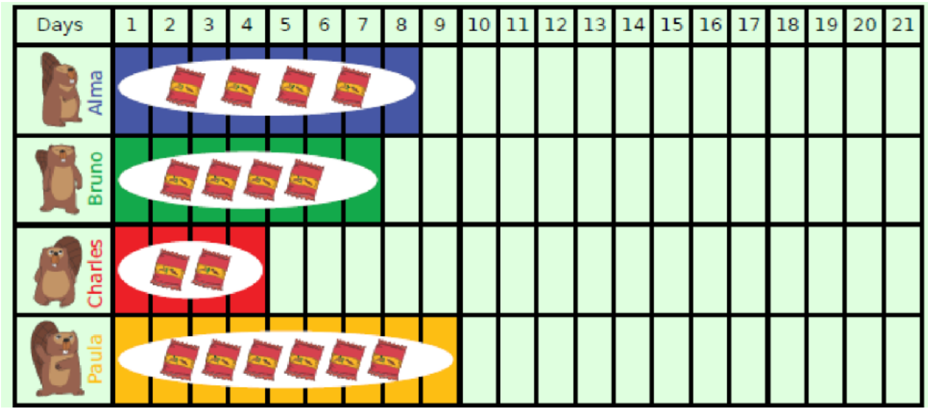
Answer Explanation

Using the given data, we can build a graph similar to the given as example in the task description:



Then we can count number of times when lines crosses particular intervals. The same temperature exactly five times corresponds to the interval (5.4;5.5) (excluding endpoint values).

5. Curd snack



Four beavers, Alma, Bruno, Charles, and Paula are going on a 3 week hike. Each beaver carries their favorite curd snack and eats a specific amount over consecutive days. On each day, a beaver will either eat no snack or one snack. As the chart shows, Alma eats 4 snacks every 8 days, Bruno eats 4 snacks every 7 days, Charles eats 2 snacks every 4 days, and Paula eats 6 snacks every 9 days.

Question / Challenge

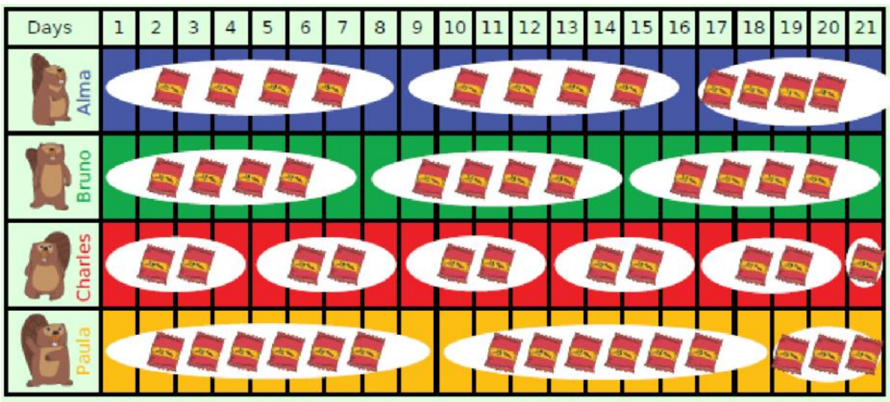
If we don't know on which days the beavers will eat their snacks, what will be the maximum number of snacks eaten during hike?

Answer Options / Interactivity Description

Integer number. Answer: 50 snacks should be brought on the hike.

Answer Explanation

The table shows the maximum number of snacks eaten by each beaver. The key to this task is to understand that the beavers may wish to eat their snacks at the beginning of their consecutive days, rather than spreading them out. So, for Alma, for example, she will eat 4 snacks during the first 8 days, 4 snacks during the next 8 days, and then there are only 5 days left before the end of the hike. Alma may wish to eat as many of her snacks as she can on during those 5 days, in which case she would eat all 4 of her snacks during the hike. So, in 21 days Alma will eat at most 12 snacks.

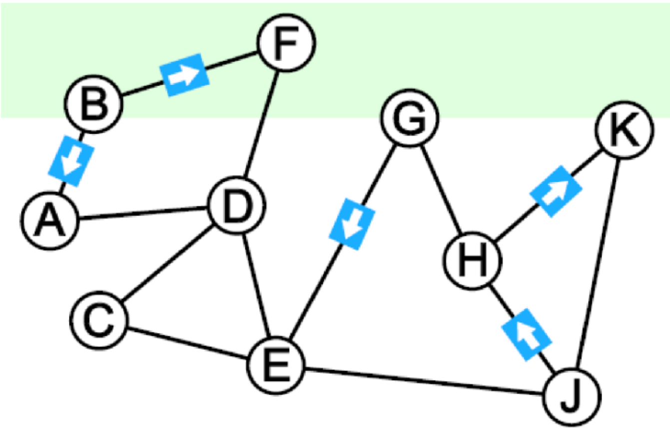


Similarly, Bruno will eat at most 12 snacks in 21 days.

Charles will eat at most 11 snacks in 21 days. There is one day left over after as you can see from the picture, and he can eat a snack on that day.
Paula will eat at most 15 snacks in 21 days. Paula can eat one snack during each of her last three days.
This totals 50 snacks in 21 days as a maximum.

6. Garden of Eden, Hotel California

In Beaver County 10 towns are connected by roads. The county council decides to make some of the roads one way roads. This is the first design.
If a town cannot be entered due to the one way roads, it is called a "Garden of Eden".
If a town cannot be left due to the one way roads, it is called a "Hotel California".
Both situations are to be avoided. Help the county council to find them.



Question / Challenge
Click on all towns that are a “Garden of Eden” or a “Hotel California” (if they are).
Answer Options / Interactivity Description
Click on problematic points in the graph
Answer Explanation
B is a “Garden of Eden”. It has two roads and both are going outside.
There is no “Hotel California”. Only towns which are ends of the arrows may satisfy this condition, but from A, F and E we can go to D, from H to K and from K to J.

7. Bebras runs

Bebras Bob has a great idea that he can use to sort a list of numbers.
He runs through the list of numbers from left to right and performs the following steps:
• He compares the current number with the next number in the list.
• If the next number is smaller, than the current number he swaps them.
• He moves to the next position in the list and repeats the steps above
• When he reaches the end of the list, this is called one pass.
Bob performs one pass on the following list of numbers:

5 3 5 6 7 4 3 6 8 4

The steps that Bob performs in the first pass are highlighted below.
(1)3556743684 (2)3556743684 (3)3556743684 (4)3556743684 (5)3556743684
(6)3556473684 (7)3556437684 (8)3556436784 (9)3556436784 (10)3556436748
After he has finished the first pass, the list of numbers looks like this:
3 5 5 6 4 3 6 7 4 8

Question / Challenge
Place the set after 3 passes:

Modification. I suggest to generate random data for this task whenever a student opens it.

Answer Options / Interactivity Description
Interactive task, see above.

Answer Explanation
The Correct answer for the list

5	3	5	6	7	4	3	6	8	4

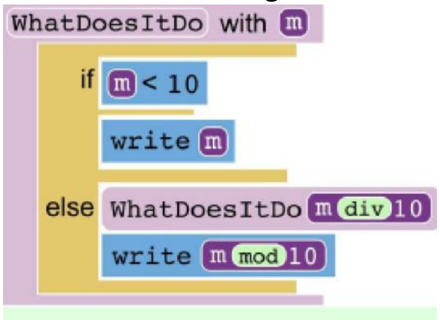
Is the following sequence:

3	5	4	3	5	6	4	6	7	8

This is the sequence after 3 iterations of the Bubble sort

8. WhatDoesItDo

Little Beaver has just learn that **div** takes the result of a division and round it down to a whole number and **mod** that takes the remainder.
For example, 90 **div** 7 is 12 and 90 **mod** 7 is 6.
Little Beaver is now given the following function which takes an integer m as input.



Question / Challenge
When m is 30241, what number will the function write?
In the window below write the result of the above function for m = 30241
Modification. I suggest to generate m whenever a student opens this task.

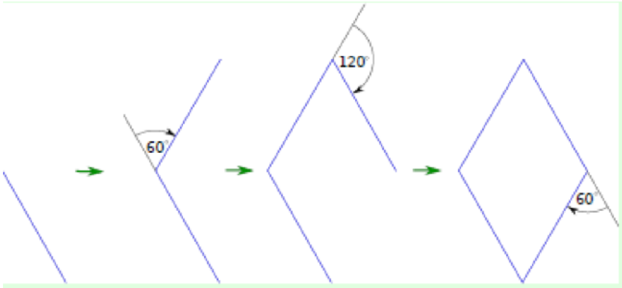
Answer Options / Interactivity Description
Interactive task – open window

Answer Explanation
The correct answer is 30241.
Since the function includes itself as part of it, the integer m is processed through the function over and over again. Each time updating the input and write down the output as shown in the following table:

	Input	p(m<10)	m div 10	m mod 10	Output
1	30241	False	3024	-	-
2	3024	False	302	-	-
3	302	False	30	-	-
4	30	False	3	-	-
5	3	True	-	-	3
4	30	-	-	0	0
3	302	-	-	2	2
2	3024	-	-	4	4
1	30241	-	-	1	1

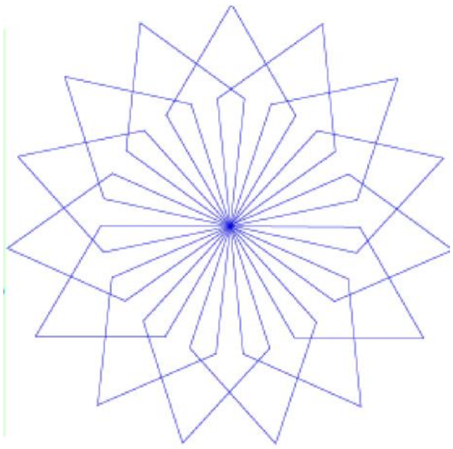
9. Diamenty

The execution of the following instructions generates a diamond. The process is shown in the picture



Diamond
repeat 2 times
move 50 steps
turn right 60 degree
move 50 steps
turn right 120 degree

Question / Challenge



In the following program:
Rosette
repeat …X… times
diamond
turn right …Y…degree
replace numbers X and Y by such numbers that the program will draw the rosette shown in the figure.

Answer Options / Interactivity Description

Interactive task – open windows

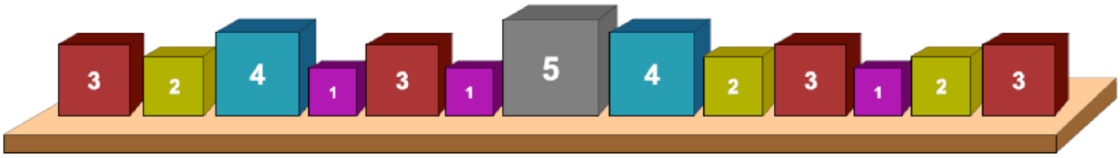
Answer Explanation

Correct answer 15 and 24.
The rosette in the picture consists of 15 diamonds. When finishing one diamond our drawing machine (or whatever it is) has the same direction as at the beginning of drawing this diamond because we turned totally 60+120+60+120 degrees.

Before drawing each new diamond we should rotate the same angle and totally we rotate 15 times returning back to the initial direction. So our rotation angle should be 360:15=24 degrees.

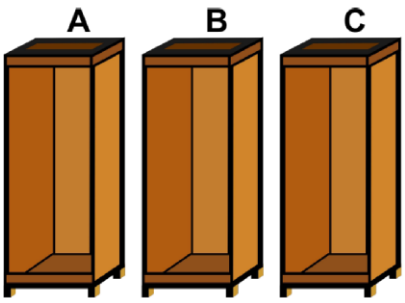
10. Boxes

Mr. Beaver has cubes of 5 different weights: 1 kg, 2 kg, 3 kg, 4kg, and 5 kg. The weight is written on each cube.
He is tidying up the room so he wants to put all the cubes into three tall cabinets: Cabinet A, Cabinet B, and Cabinet C. Each cabinet can only hold a maximum weight of 15 kg.
Another rule is that a heavier cube cannot be placed on top of a lighter cube.
Mr. Beaver puts the cubes in the cabinets in the order that they are lined up starting from the cube on the left. For each cube, he puts it in the first cabinet (always starting with cabinet A), where it can fit, according to the weight rules.



Question / Challenge

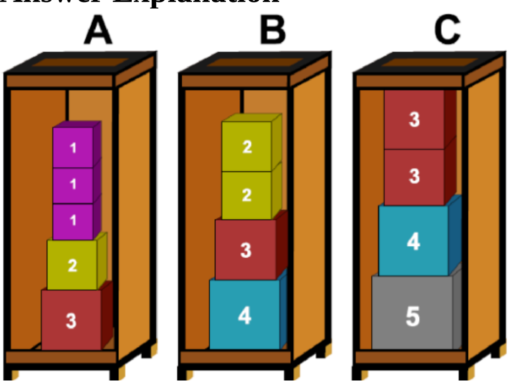
Help Mr. Beaver to put all the cubes into the cabinets. Drag the cubes into the cabinets, following the rules.



Answer Options / Interactivity Description

There should be 3 cabinets and 13 cubes. The cubes must be pulled into the cabinets, in the right order, one on top of the other.
At any time, only the first available cube on the shelf can be moved. There is an undo button that puts the last placed cube back on the shelf.

Answer Explanation

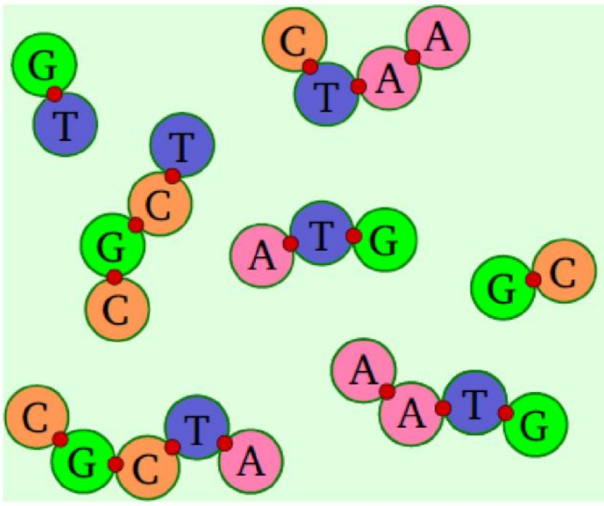


The correct answer is:
Place a cube on top of another cube with the nearest weight.
The first cube of weight 3 goes into Cabinet A

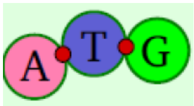
The second cube of weight 2 will be placed over the cube of weight 3, in Cabinet A, in order to let the Cabinet B have a heavier cube at the bottom.
The cube of weight 4 will be placed in Cabinet B,
The cube of weight 1 will be placed in Cabinet A, over the cube of weight 2 (instead of putting it into Cabinet B over the cube of weight 4, thus leaving room for a cube with a higher weight).
Follow the same principle until all the cubes are arranged in cabinets.

11. Genome decoding

DNA molecules are a chain made of four nucleobases: Cytosine(C), Guanine(G), Adenine(A), and Thymine(T). A Scientist
is trying to recreate a DNA molecule from the pieces below.



The molecule letters can be read from both sides (left to right and right to left).

For example, 

can be read as "ATG" or "GTA".

Question / Challenge

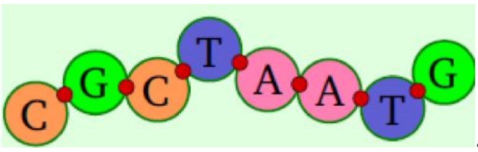
What is the shortest possible chain that contains all these pieces?

Answer Options / Interactivity Description

Enter the word, consisting of letters A, C, G, T.

Answer Explanation

The answer is CGCTAATG or GTAATCGC (see the chain below)

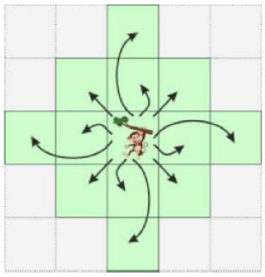


.

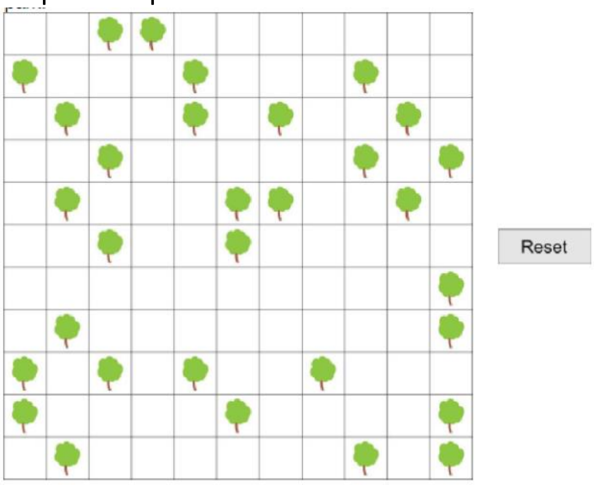
We can see that this chain contains all requires pieces. CGCTA and AATG can intersect only by one letter, so it is the
shortest one

12. Jumping Jack

Jack is not a beaver. He is a monkey living in a park. From one tree, he can jump to another tree if it's either up to two cells away horizontally or vertically, or one cell away diagonally, as shown in the diagram.
Jack plays a game in which he jumps to as many different trees as possible without touching the ground. He can start from any tree in the park.



Map of the park:



Question / Challenge

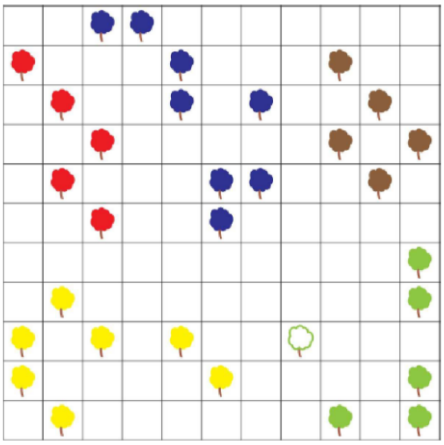
Color in blue, the biggest number of different trees Jack can visit in one go without touching the ground.
Click on a tree to change its color. It will flip between green, blue and gray. You can use green or gray to help you solve the task, but only blue trees are part of the answer.

Answer Options / Interactivity Description

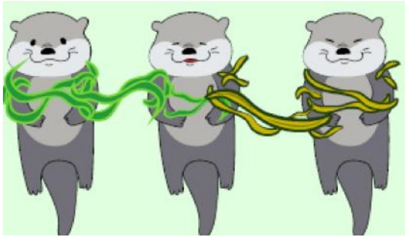
Clicking on a tree flips its color from green to dark blue to gray, then to green again.
Clicking on the reset button colors all trees back to green.

Answer Explanation

In this diagram, Jack can visit the 8 trees that are colored in dark blue. We colored other trees with multiple colors, to show the different groups of trees.
There are essentially six groups of trees in the park. If Jack starts on a tree we painted yellow, he can reach all yellow trees, and no trees of other colors.
How do we find such groups?
Pick a random tree and color it as you wish. Then use the same color for all trees that are reachable from it. And all trees that are reachable from those trees, too. And so on, until you cannot reach any other trees. If there are any trees you haven't colored yet, take another color and start again from a random uncolored tree. Your coloring simulates Jack's exploring.

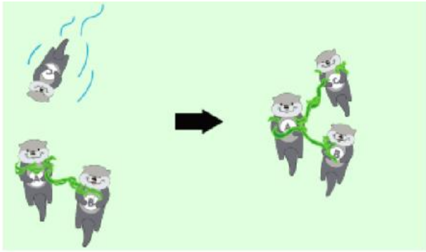


13. Napping Together

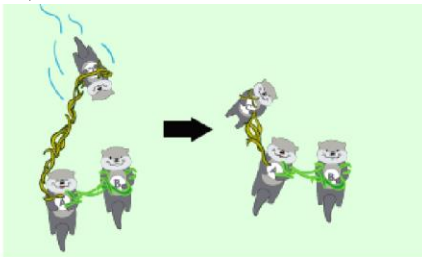


When two otters in OtterKingdom meet each other, they will wrap a seaweed around themselves so that they can stay together during nap time. However, to avoid knots, if two otters are already connected, they won't wrap another seaweed.
For instance: If otters meet each other in following order: A - B, A - C, B - C

OtterB meets otterA. They wrap a seaweed around themselves.



OtterC meets otterA. They wrap a seaweed around themselves.



OtterC meets otterB. Since they are already conncted through otterA, they won't wrap a seaweed around themselves.

Otters meet each other in following order:
A - B, A - C, B - C, D - E, A - E, D - F, A - F

Question / Challenge

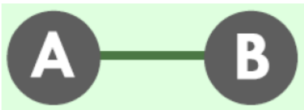
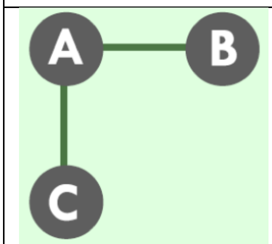
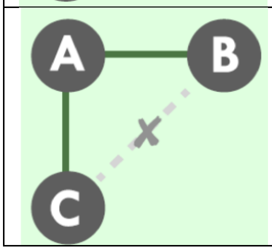
How many seaweeds are wrapped around otterA?

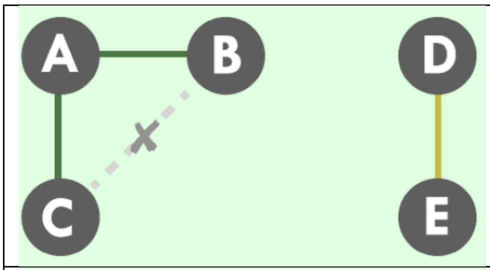
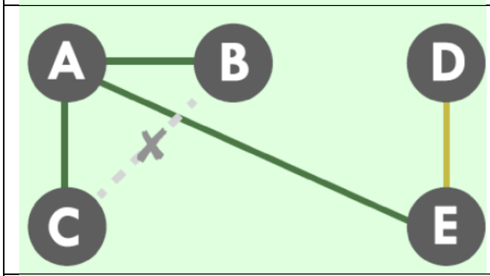
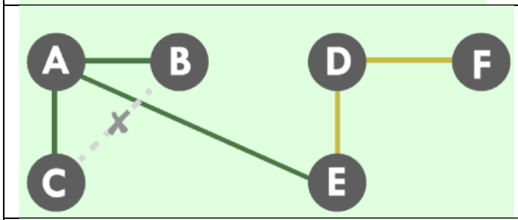
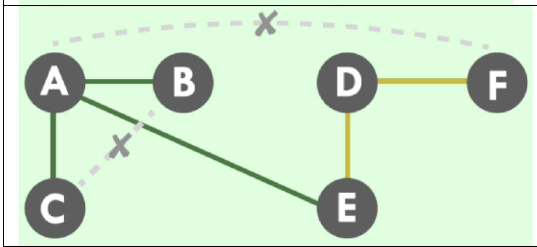
Answer Options / Interactivity Description

Integer numbers [0,10]

Answer Explanation

The correct answer is 3.

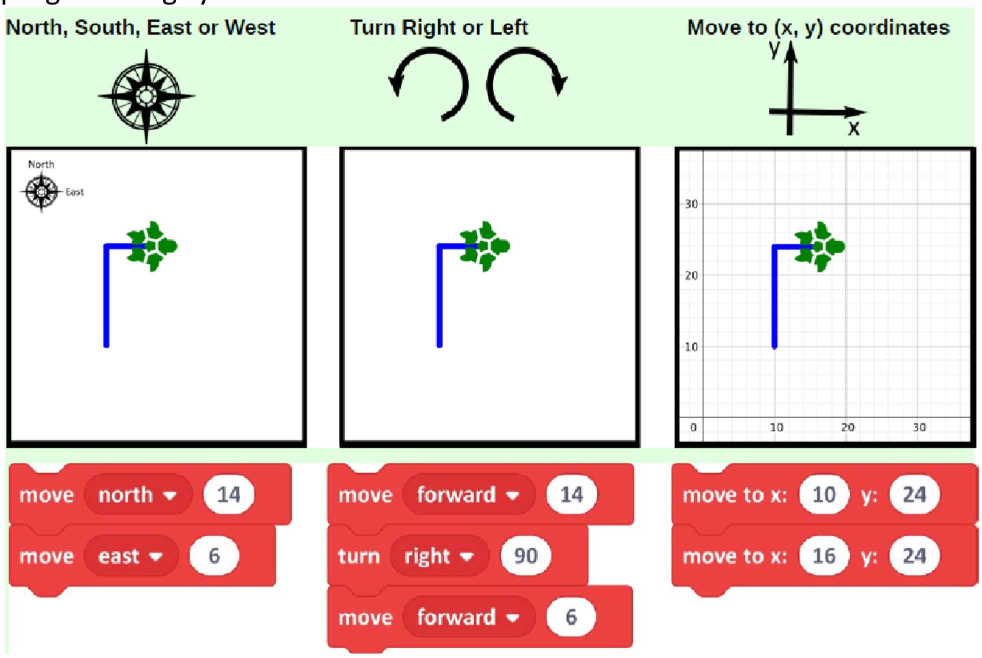
	A meets B. They wrap a seaweed around themselves. One seaweed is wrapped around otter A at this point.
	A meets C. They wrap a seaweed around themselves. Two seaweed is wrapped around otter A at this point.
	B meets C. Since they are already conneted, they won't wrap any seaweed around themselves.

	D meets E. They wrap a seaweed around themselves.
	A meets E. They wrap a seaweed around themselves. Three seaweed is wrapped around otter A at this point.
	D meets F. They wrap a seaweed around themselves.
	A meets F. Since they are already conneted, they won't wrap any seaweed around themselves.

Thus, only three seaweeds are wrapped around otter A.

14. Robot Drawing

A school has a turtle robot that has a pen which draws lines when the robot moves. The robot's movement can be programmed in different ways using three different programming systems:

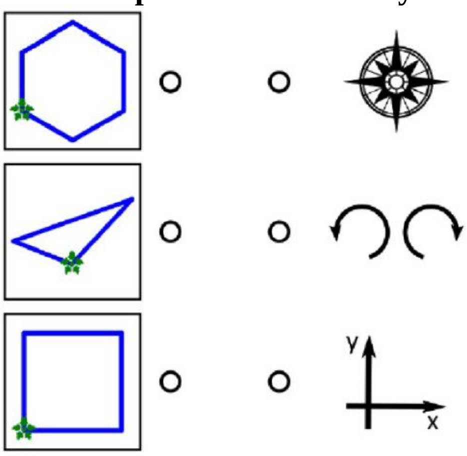


The three sets of programming commands above make the robot draw the same picture. The robot can only be programmed using whole numbers without decimals.

Question / Challenge

Connect the pictures below to the correct programming system so that the robot can be programmed to draw the three pictures using as few move to (x, y) coordinates programming commands as possible. Each programming system can only be used to draw one picture.

Answer Options / Interactivity Description



Connect points using 3 lines.

Drag and drop version: move the drawings to the symbol of the appropriate drawing system

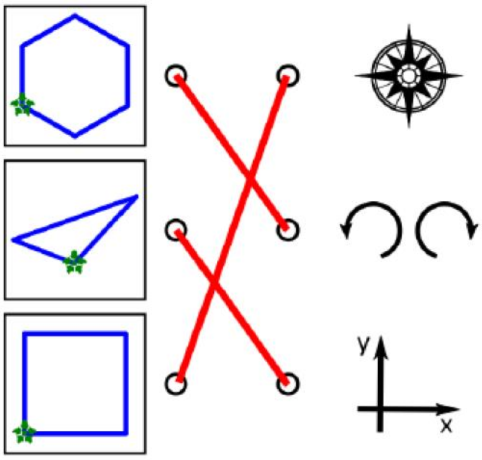
Answer Explanation

Correct answer – on the right:

Sally has two constraints:

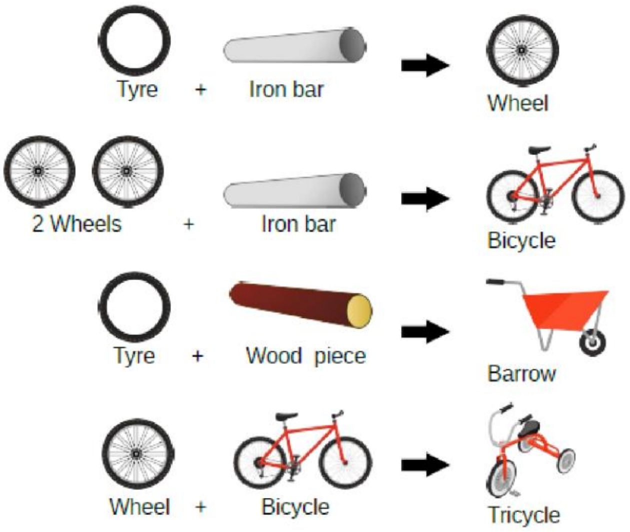
1. She must use each of the three programming systems
2. She wants to avoid using as many move to (x, y) coordinates programming commands as possible.

The North South West East programming system can only move the robot horizontally or vertically. That means that the hexagon and triangle can't be drawn with this system, only the square can be drawn with this system.
Sally can use the Coordinates programming system for both of the remaining drawings. The triangle has three points and thus needs three coordinate commands, the hexagon has six. This means the triangle should be drawn with the coordinates programming system to satisfy the second constraint. But this is only possible if the robot can draw a hexagon using the Turn Left and Right system.
The hexagon can be programmed using the Turn Left and Right programming system because the turn block allows the programmer to choose how far to turn. Because a hexagon has six of the same angles, the robot repeats going straight and turning 60o a total of 6 times.



15. Upcycling A

Beavers hate waste. They like to use old worn out things as materials to make new usefulitems. This is called upcycling. It is shown below what materials are required to make a wheel, a bicycle, a barrow, and a tricycle.



Doreen loves upcycling and likes to sell the items she is making. They can be sold at the market for these prices:

Question / Challenge

Doreen has these materials: 4 tyres, 4 iron bars and 1 wood piece. What is the most money she can make by upcycling when she sells the items she makes?

(Give your answer in the form of an integer)

Answer Options / Interactivity Description

Answer: 20

The most that Doreen can make is £20.

Answer Explanation

The value of a tricycle is more than a bicycle and a wheel so Doreen should aim to make a tricycle.

A tricycle uses: 2 wheels and 1 iron bar (to make a bicycle), and another wheel.

3 wheels use: 3 tyres and 3 iron bars.

This leaves 1 tyre and 1 wood piece.

The highest value item Doreen can now make is a barrow.

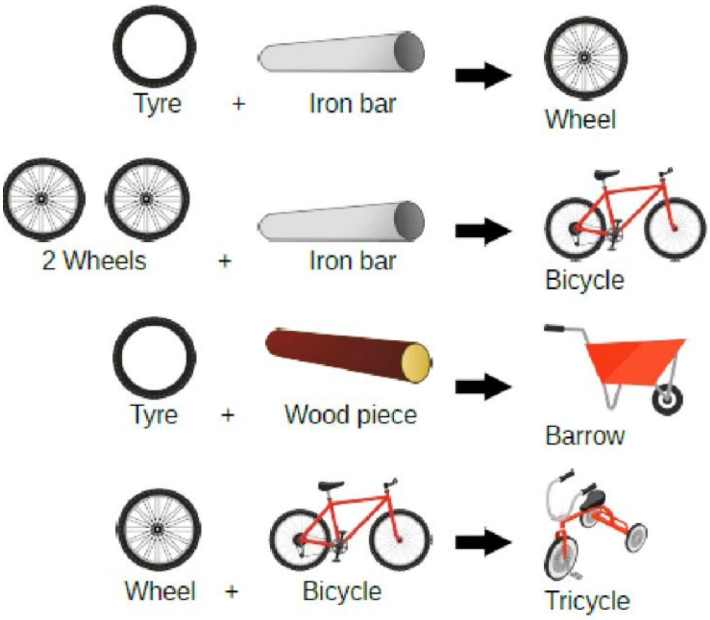
Total value of 1 tricycle + 1 barrow = 15 + 5 = £20.

This amount of £20 is the most money that Doreen can make. This occurs when she always tries to build an item of the highest possible value, given what materials she has available.

This works for the values in this task but will not always work. Can you convince yourself of this?

16. Upcycling B

Beavers hate waste. They like to use old worn out things as materials to make new useful items. This is called upcycling. It is shown below what materials are required to make a wheel, a bicycle, a barrow, and a tricycle.



Beavers hate waste. They like to use old worn out things as materials to make new useful items. This is called upcycling. It is shown below what materials are required to make a wheel, a bicycle, a barrow, and a tricycle.

Question / Challenge

Doreen has these materials: 6 tyres, 6 iron bars and 2 wood pieces. What is the most money she can make by upcycling when she sells the items she makes?
(Give your answer in the form of an integer)

Answer Options / Interactivity Description

Answer: 30
The most that Doreen can make is £30.

Answer Explanation

It might be tempting to think that Doreen should build a tricycle because this is the item that can be sold for the most total money. If she does, it requires 2 wheels and one iron bar (to

make a bicycle) and another wheel. The 3 wheels need 3 tyres and 3 iron bars. So this leaves Doreen with 3 tyres, 2 iron bars, 2 wood pieces.
Now, Doreen no longer has the three iron bars needed to make another bicycle so she can only make wheels and barrows. Since she has the same number of iron bars as wood pieces, and barrows can be sold for more than wheels, she should then make two barrows.
This uses 2 tyres and 2 iron bars, leaving 1 tyre and 2 iron bars.
It would now be possible to make a wheel, leaving 1 iron bar which cannot be used for anything else.
The total value of items made is 1 tricycle + 2 barrows + 1 wheel = 15 + 10 + 1 = £26. So £26 is the most money Doreen can make if she builds a tricycle.
But what if Doreen does not build a tricycle?
Doreen could make two bicycles using 2 tyres and 4 iron bars, leaving 4 tyres, 2 iron bars and 2 wood pieces. Then, she could also make 2 barrows, leaving just 2 iron bars unused.
The total value of this second strategy is 2 bicycles + 2 barrows = 20 +10 = £30. This is the maximum that can be earned given the resources available.
Can you convince yourself that no other scenarios can produce items with a greater total value?

Co-funded by the European Union

Appendix 1: Material for students - future teachers

Mayer's Principles of Multimedia Design and Learning

In the book *Multimedia Learning*, Richard Mayer discusses twelve principles on the design and organisation of multimedia presentations that make more effective course resources to support student learning. These principles inform the delivery of course content, whether flipped course resources meant for students to view outside of class time (such as recorded lectures), or in-class course resources typically used during traditional lecture time (such as slides).

Principle	Description	How to Address	Cognitive Load Effect
Multimedia	People learn better from words and pictures than from words alone.	• Include images to illustrate key points. • Ensure that all images enhance or clarify meaning. • Favour static images over animations (with some exceptions).	Optimises germane load
Coherence	People learn better when you exclude extraneous material.	• Include only graphics, text, and narration that support learning goals. • Don't use background music. • Use simple visuals.	Reduces extraneous load
Signalling	People learn better when you use cues that highlight the organisation of the essential material.	• Use arrows, highlighting, and other signals to draw attention to important information. • Include a slide that indicates the organisation of your presentation and refer back to it when you advance to a new section.	

Redundancy	People learn better from graphics and narration than from some graphics, narration, and printed text.	• When delivering a narrated presentation, use either graphics or text, but not both. • Minimise the use of text during a narrated presentation.	

Spatial Contiguity	People learn better when you present corresponding words and pictures near rather than far from each other on the page or screen.	• Place text in close proximity with the graphics it refers to. • Provide feedback close to the questions or answers it refers to. • Present directions on the same screen as an activity. • Have people read any text before beginning an animated graphic.	
Temporal Contiguity	People learn better when you present corresponding words and pictures simultaneously rather than successively.	• Time the narration appropriately to play along with the animations.	
Segmenting	People learn better when you present a multimedia message in user-paced segments rather than as a continuous unit.	• Allow users to control the pace of the lesson. • Break down long segments of material into smaller pieces.	Manages intrinsic load

Pre-training	People learn more deeply from a multimedia message when they know the names and characteristics of the main concepts.	• Define key terms (such as names, definitions, locations, and characteristics) before beginning a process-based presentation, either in a separate presentation, handout, or similar material.	
Modality	People learn more deeply from pictures and spoken words than from pictures and printed words.	During a narrated presentation with graphics, avoid using on-screen text, unless it: • Lists key steps • Provides directions • Provides references • Presents important information to non-native English speakers	
Personalization	People learn better from multimedia presentations when you use conversational language (rather than formal).	• Use contractions. • Use first and second person (“I,” “you,” “we,” “our,” etc.). • If using a script, try to sound natural. • Use polite speech (“please,” “you might like to,” “let’s,” etc.).	Optimises germane load
Voice	People learn better when narration is spoken in a human voice rather than in a machine voice.	• Include narration that is performed by a human rather than a computer.	
Image	People do not necessarily learn better when the speaker’s image is on the screen.	• Avoid including a video of yourself during an asynchronous multimedia presentation containing pictures and words. • Consider including your face when: • There are no words or pictures. • You wish to establish an instructor or social presence.	

University of Groningen. Mayer's Principles of Multimedia Design and Learning*:* https://www.rug.nl/education/online-teaching/tools/video/diy-video-studio-harmoniegebouw/multimedia-principles.pdf *Adapted from Mayer, R. E. (2009). Multimedia learning (2nd ed.). Cambridge, England: Cambridge University Press.*

Appendix 2: Examples of Analyses on Interactive Bebras Tasks

Hence, any Bebras task creator should be aware of that he/she should:

1. Try to address as many multimedia principles as possible
2. Decide the difficulty level according to Bloom's taxonomy
3. Select best interactivity type relevant for the question

Below we have allocated several Bebras interactive tasks from 2021-2022.

ID and name of the Bebras task	Mayer's multimedia Principles addressed (M1-M7)	Difficulty level according to Bloom's taxonomy (B1-B6)	Interactivity type relevant for the task
2022-AU-03, Lights On	M1, M2, M3, M4, M7	B3	Click-On-Object
2022-CH-03a, b, Super Security System	M1, M3, M4, M6, M7	B4	Drag & Drop
2022-CH-04, Greedy Trolls	M1, M2, M3, M4, M7	B5	Drag & Drop
2022-DE-03, Listen and Walk	M1, M3, M4, M5, M7	B2	Click-On-Object
2022-DE-07, Favorite Movie	M1, M2, M3, M4, M7	B6	Click-to-Change
2022-IE-02, Forest party	M1, M2, M3, M4, M7	B3	Drag & Drop
2022-IN-01, Learn Traditional Art	M1, M2, M3, M4, M7	B3	Drag & Drop
2022-LT-05, Overlapping villages	M1, M2, M3, M4, M7	B5	Open Integer
2022-NL-03, A gift for the president	M1, M2, M3, M4, M7	B6	Open Integer
2022-TR-02, Rug Weaving	M1, M2, M3, M4, M5, M7	B3	Click-On-Object to Choose
2022-TW-03: Strawberry	M1, M2, M3, M4, M5, M7	B6	Open Integer

2022-VN-05, Colourful tower	M1, M2, M3, M4, M5, M7	B3	Click-On-Object to Choose
2021-AT-01, Forest Observation	M1, M2, M3, M4, M7	B5	Click-On-Object
2021-AU-04a, b, c, Ada's Marble Machine	M1, M2, M3, M4, M5, M6, M7	B4	Click-On-Object
2021-CA-01, Cuckoo Birds	M1, M2, M3, M4, M7	B4	Drag & Drop
2021-CH-04c1, Strawberry Thief	M1, M2, M3, M4, M5, M7	B5	Click-On-Object
2021-CH-13, Fruit Stack	M1, M2, M3, M4, M5, M7	B5	Drag & Drop
2021-CH-26a, 2021-CH-26b, Che Connie	M1, M2, M3, M4, M5, M6, M7	B6	Drag & Drop
2021-CY-02, New residents to Beaverland	M1, M2, M3, M4, M7	B6	Open Text
2021-CZ-01, Secret Of The Diary	M1, M2, M3, M4, M7	B4	Open Text
2021-DE-01, Treasure Hunt	M1, M2, M3, M4, M7	B3	Click On-Object to Choose
2021-DE-04, Detective Lawn Mower	M1, M2, M3, M4, M7	B4	Click On-Object to Choose
2021-DE-08a, b, c, Preferences	M1, M2, M3, M4, M6, M7	B3	Draw lines (Connect objects)
2021-HU-02, Fault Detection	M1, M2, M3, M4, M5, M7	B4	Click-On-Object
2021-UZ-01a, b, c, Kangaroo	M1, M2, M3, M4, M6, M7	B5	Click-On-Object