

Why some material is difficult to learn

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Why is learning difficult?

Productive (intrinsic) cognitive load

&

Wasteful (extraneous) cognitive load

Element interactivity

- Elements of information: all input attributes that could be encoded as memory traces
- Relations between elements of information define the **structure of information**
- Substantial WM capacity and conscious effort could be required for processing and encoding relations among elements of information (**WM load**)

Suppose 5 days after the day before yesterday is Friday.

~~What day of the week is tomorrow?~~

Solve for x : $ax=b$

Transitive interference problems:

Halford, Maybery, and Bain (1986).

a is larger than b

b is larger than c

b is larger than c, is larger than b,

Which is the largest?

When the cognitive load is heaviest?

The integration of two premises requires considering all the elements (a, b, and c) and their relations concurrently bringing element interactivity to its highest point

This was the course that the student, whom the school that was criticized by the newspaper expelled, failed.

Four sentence nodes to parse at one time: *the course was, the student failed, the school expelled, and the newspaper criticized.*

Learning foreign language:

Vocabulary vs grammar

Cognitive load:

Load that performing a particular task imposes
on working memory

(due to processing interacting elements of information)

Intrinsic cognitive load: (productive load)

- Determined by the degrees of interactivity between essential for learning elements of information (relative to levels of learner prior knowledge)

Example: These following problems have high intrinsic load

After 6 passengers had left the bus, 9 passengers remained. How many passengers were on the bus initially? (Change)

Peter's book contains 50 pages. Peter read 15 pages in the morning. In the afternoon, he read the remaining pages and finished the book. How many pages did Peter read in the afternoon? (Group)

Managing intrinsic load:

Simplify task by omitting some of the interacting elements initially

Appropriately segment and sequence tasks from simple to complex

Extraneous Cognitive Load (Wasteful load):

- Determined by the manner in which the information is presented to the learners and the learning activities required of them

Efficient learning

Optimizing productive and minimizing wasteful cognitive load

Do not do anything that gets in the way of learning

Some source of wasteful cognitive load:

- Introducing unnecessarily too many new elements of information in WM
- Extensive search and match processes
- Insufficient guidance for novice learners

- Procedure of finding Angle X:

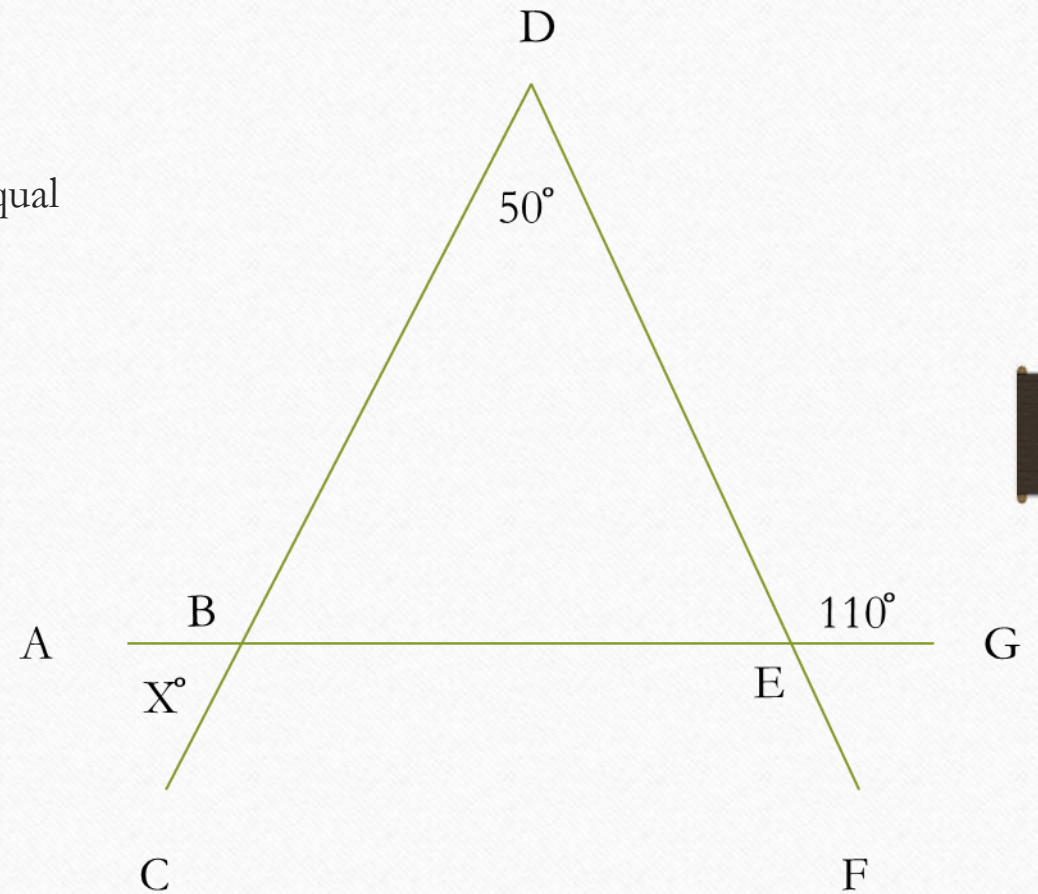
Angle DBE = Angle DEG - Angle BDE (external angle of triangle equal the sum of the opposite internal angles)

$$= 110^\circ - 50^\circ$$

$$= 60^\circ$$

Angle x = Angle BDE (vertically opposite angles are equal)

$$= 60^\circ$$



Germane cognitive load

Cognitive activities enhancing learning (self-explanations, varying problem contexts etc.)

Part of intrinsic load

Germane resources: actual working memory resources devoted to productive learning (to intrinsic load)

Types of cognitive load

Intrinsic Load

Productive Load

Extraneous Load

Wasteful Load

No overload situation

Intrinsic Load

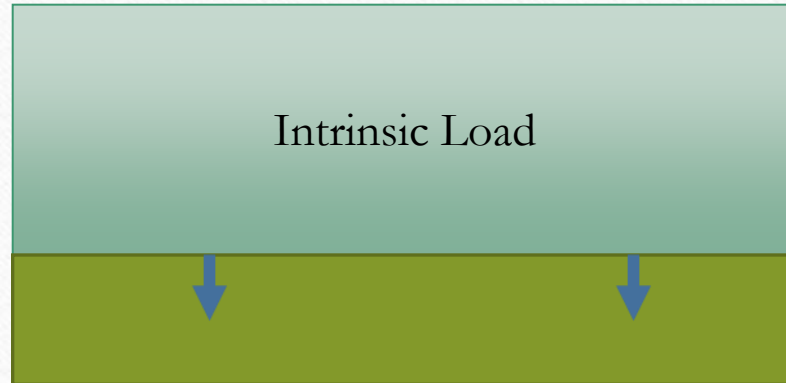
Extraneous Load

Cognitive overload due to excessive extraneous load

Intrinsic Load

Extraneous Load

Cognitive Load Theory (CLT): reduce extraneous load, increase productive load



Cognitive load due to excessive intrinsic load



Intrinsic Load

Cognitive Load Effects

Cognitive load effects	Primary cognitive load course
Goal-free	Extraneous
Worked example	Extraneous
Split-attention	Extraneous
Modality	Extraneous
Redundancy	Extraneous
Expertise Reversal	Extraneous
Guidance fading	Extraneous
Completion	Extraneous
Element Interactivity	Intrinsic
Isolated/interacting elements	Intrinsic
Imagination	Germane

Problem solving as an instructional method

Conventional problems present students with a set of given data (the known information) and a well defined goal.

Why conventional problems may not be an optimal instructional method?

What are alternatives?

Evidence of interference between conventional problem solving and schema acquisition:

Puzzle problems

(Maver & Sweller, 1982)

mathematics and science problems

(Sweller & Cooper, 1985; Sweller, Mewer, & Ward, 1983).

Solve for x: $5x = -4$

$$x = -4/5$$

$$5x/5 = -4/5$$

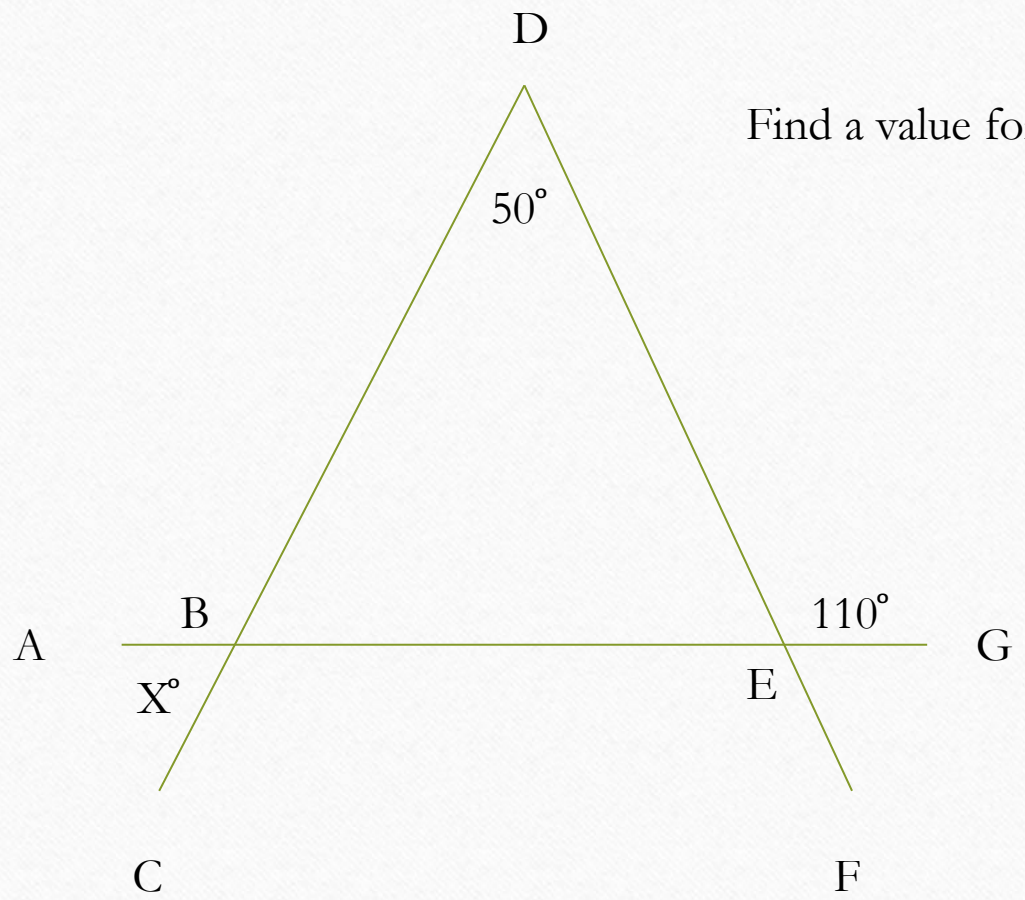
Solve for x: $5x = -4$

If you don't have a schema for solving a problem, you may use trial-and-error search or means-ends analysis

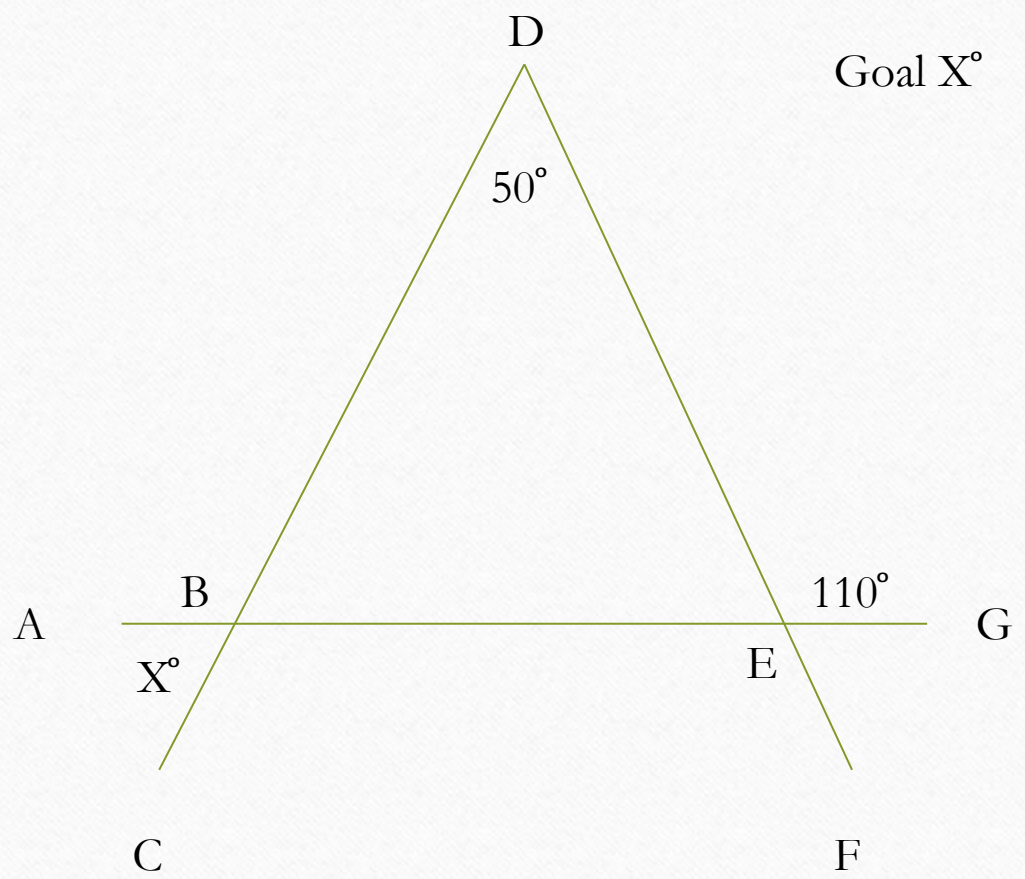
Means-ends analysis:

- The initial problem state
- The current problem state
- The goal state
- Defining differences between these states
- Finding moves to reduce those differences
- Considering sub-goals that may lead to a solution

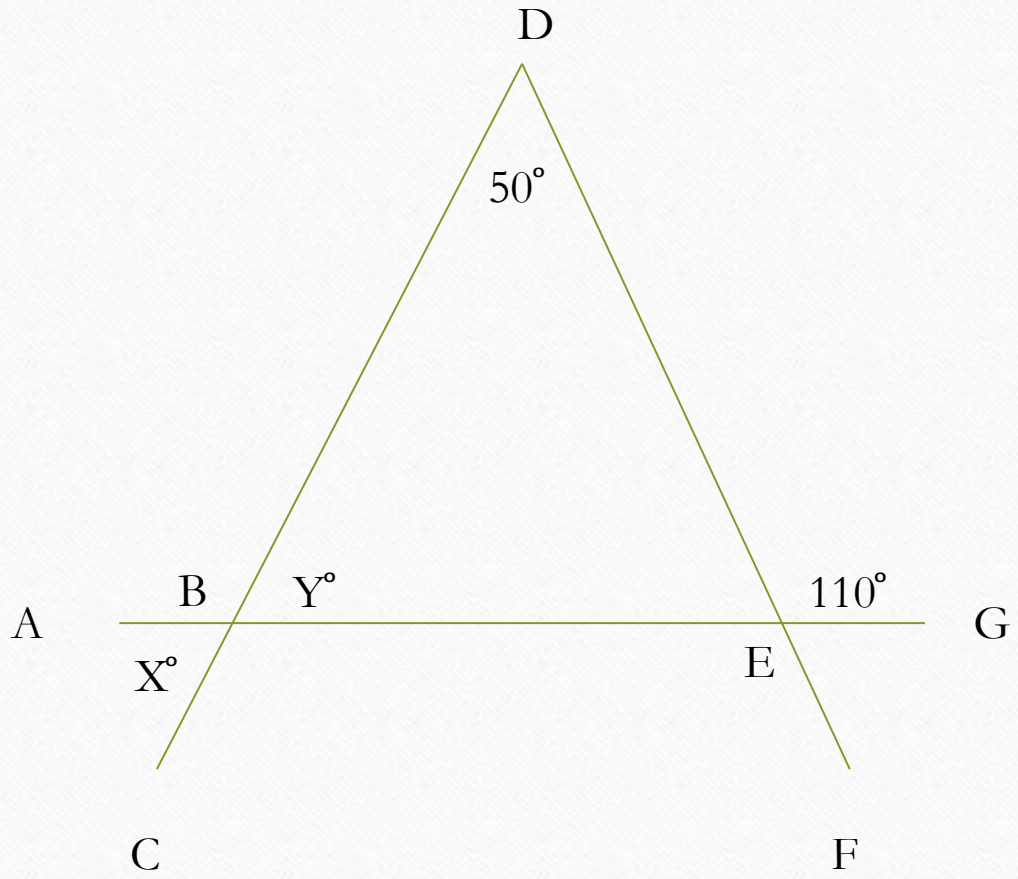
Means-ends analysis often results in working backwards from the goal



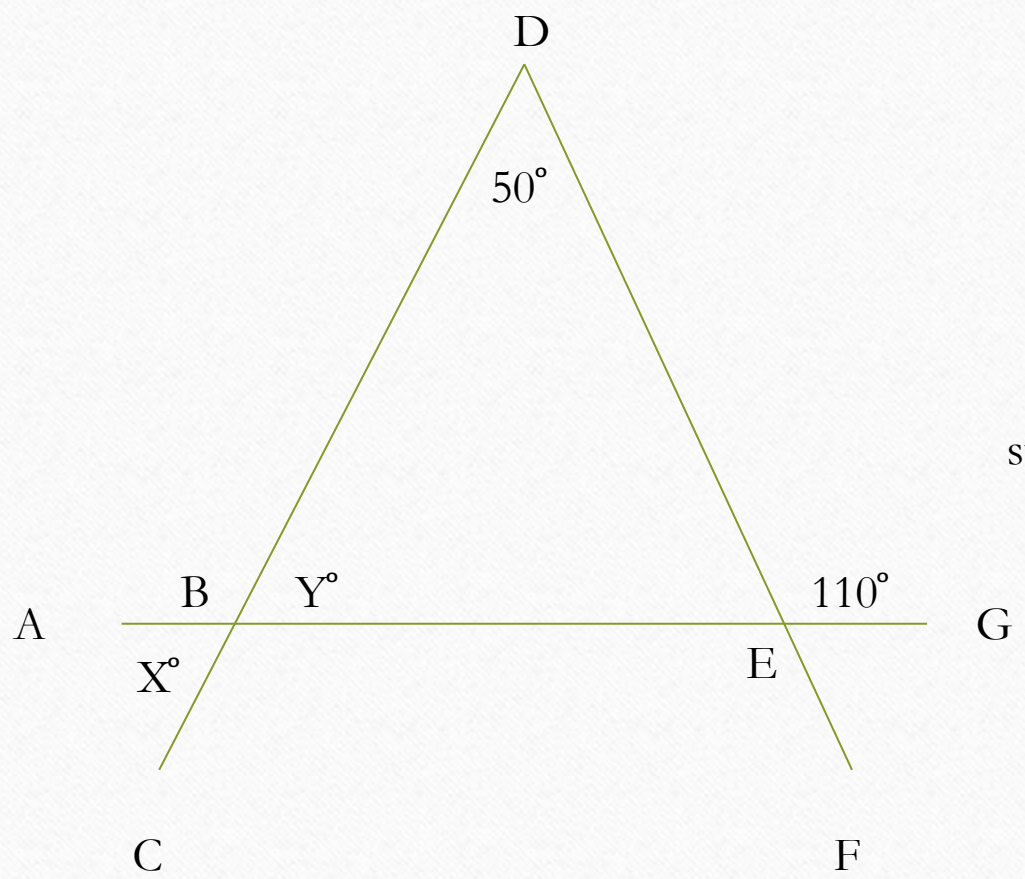
Find a value for angle X



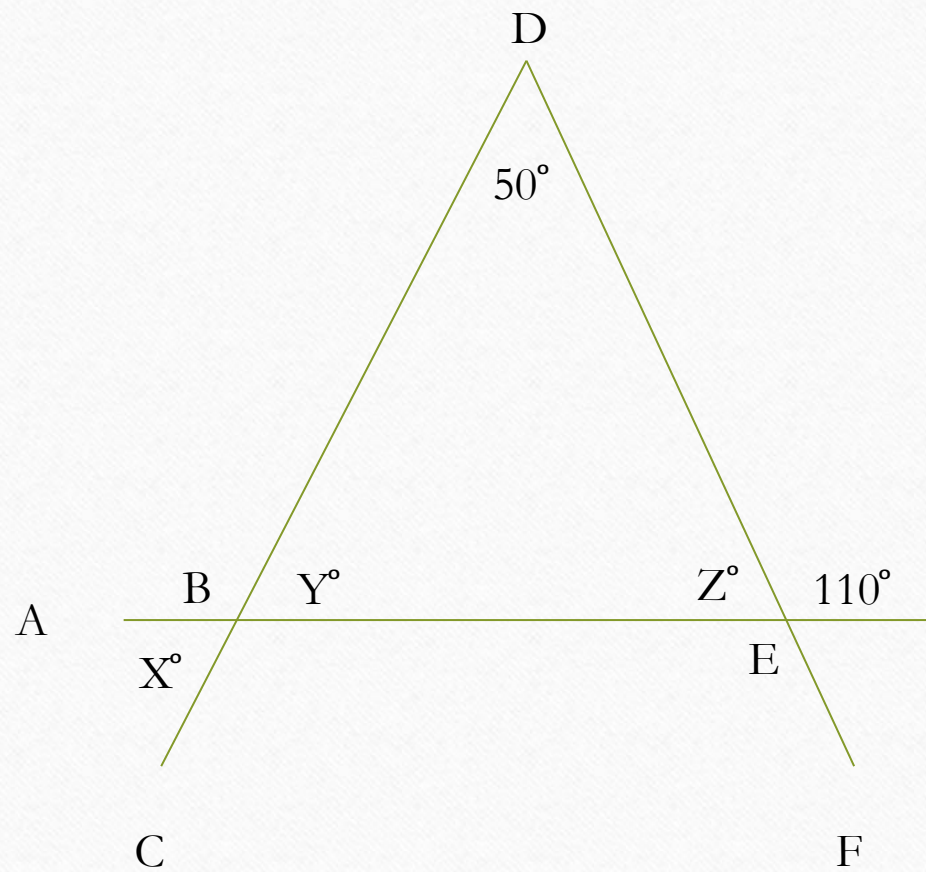
Goal X°



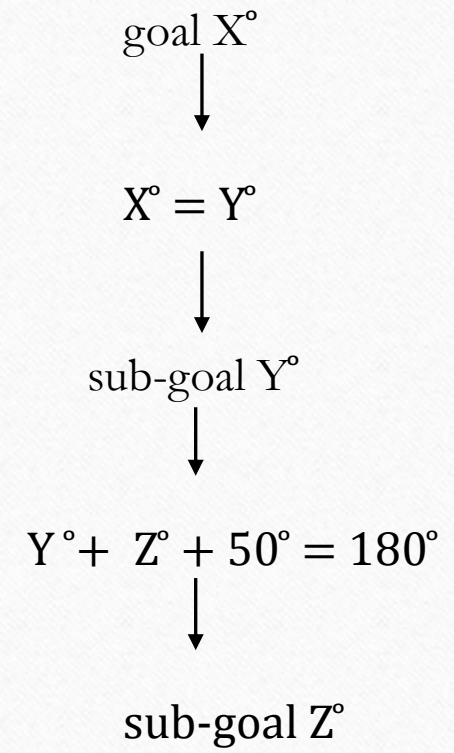
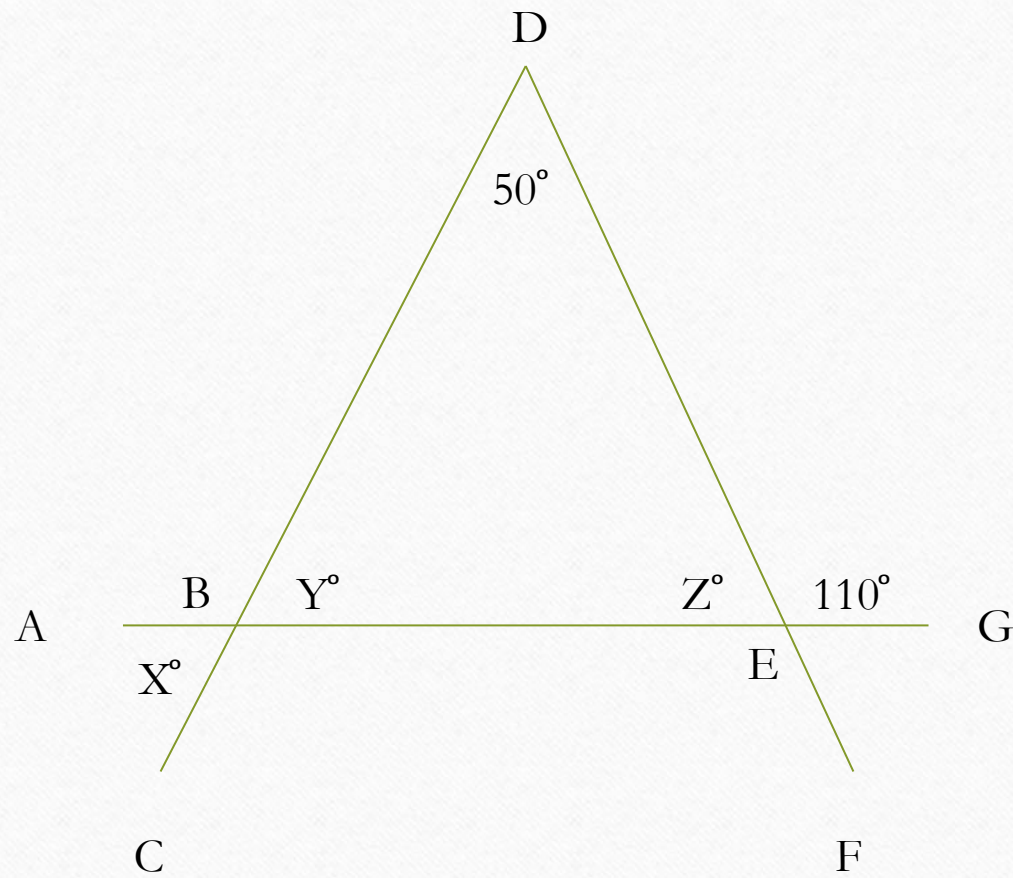
goal X°
 \downarrow
 $X^\circ = Y^\circ$

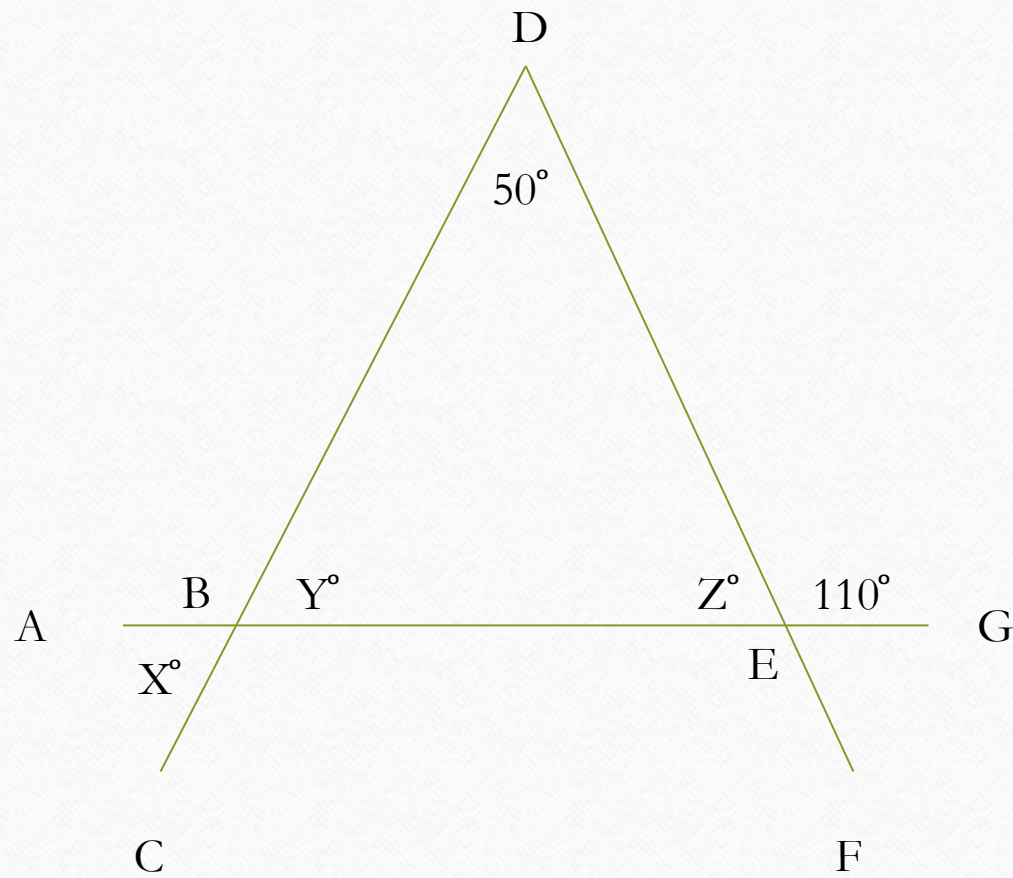


goal X°
↓
 $X^\circ = Y^\circ$
↓
sub-goal Y°

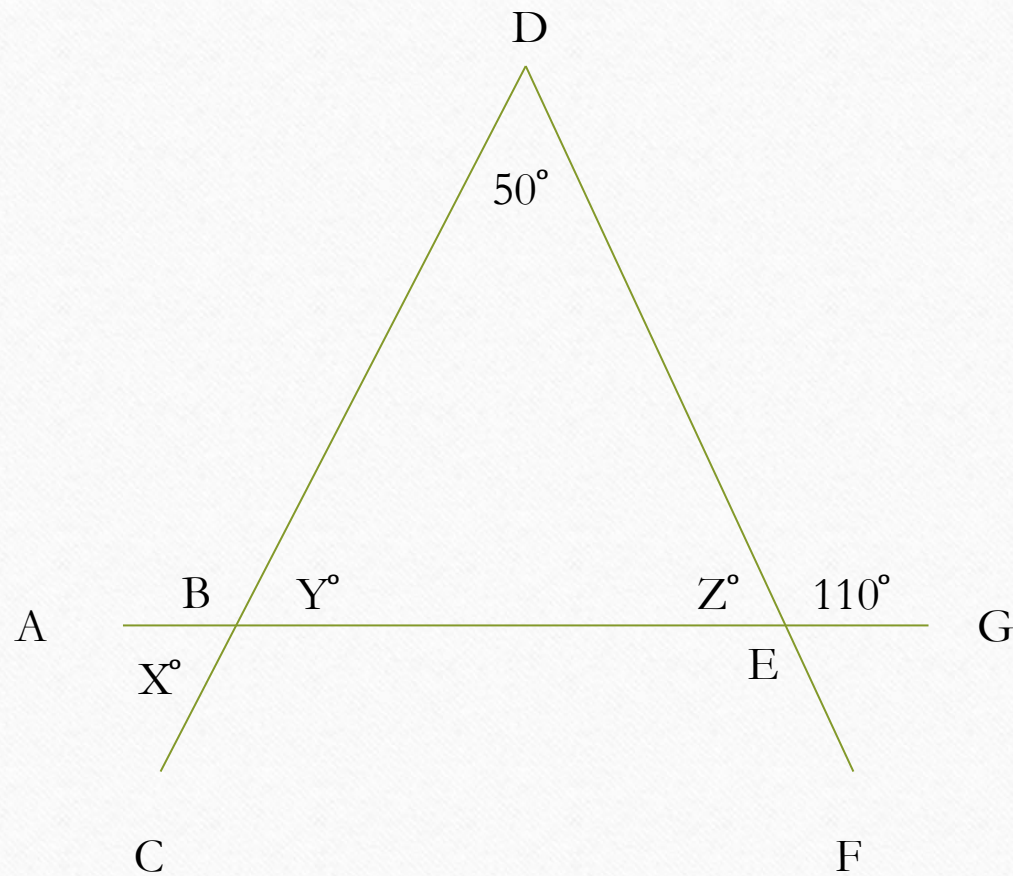


goal X°
↓
 $X^\circ = Y^\circ$
↓
sub-goal Y°
↓
 $Y^\circ + Z^\circ + 50^\circ = 180^\circ$

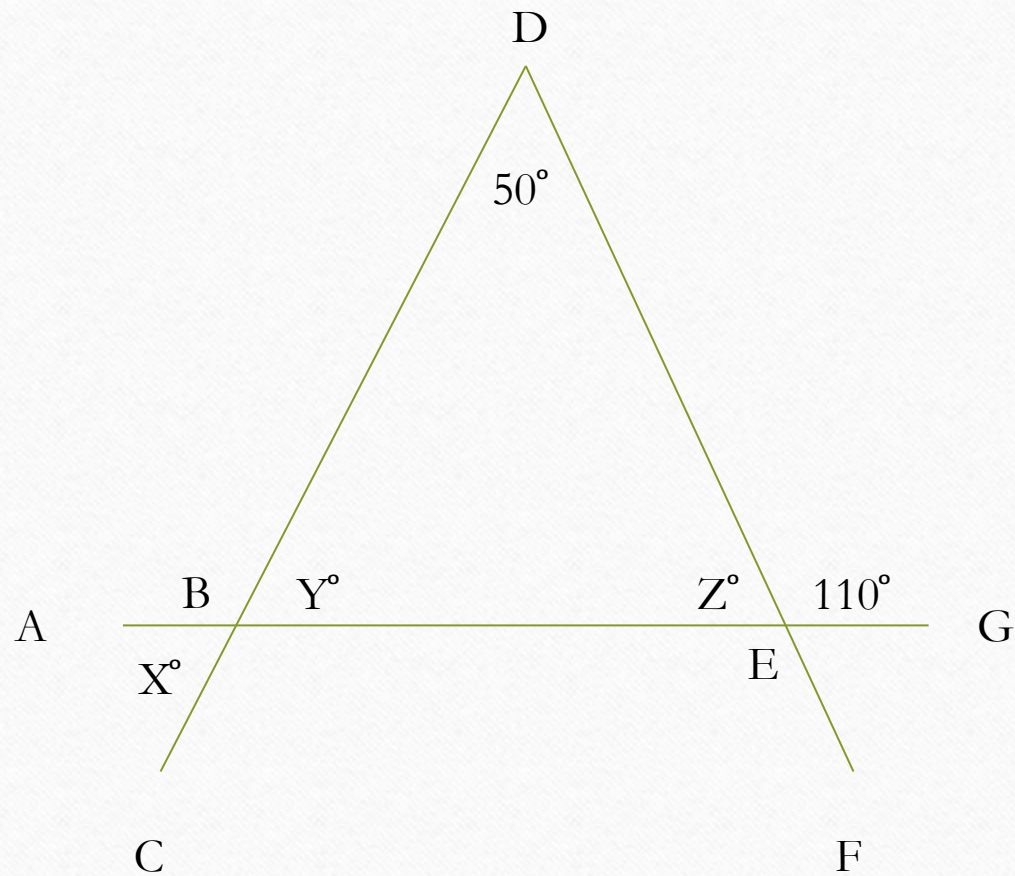




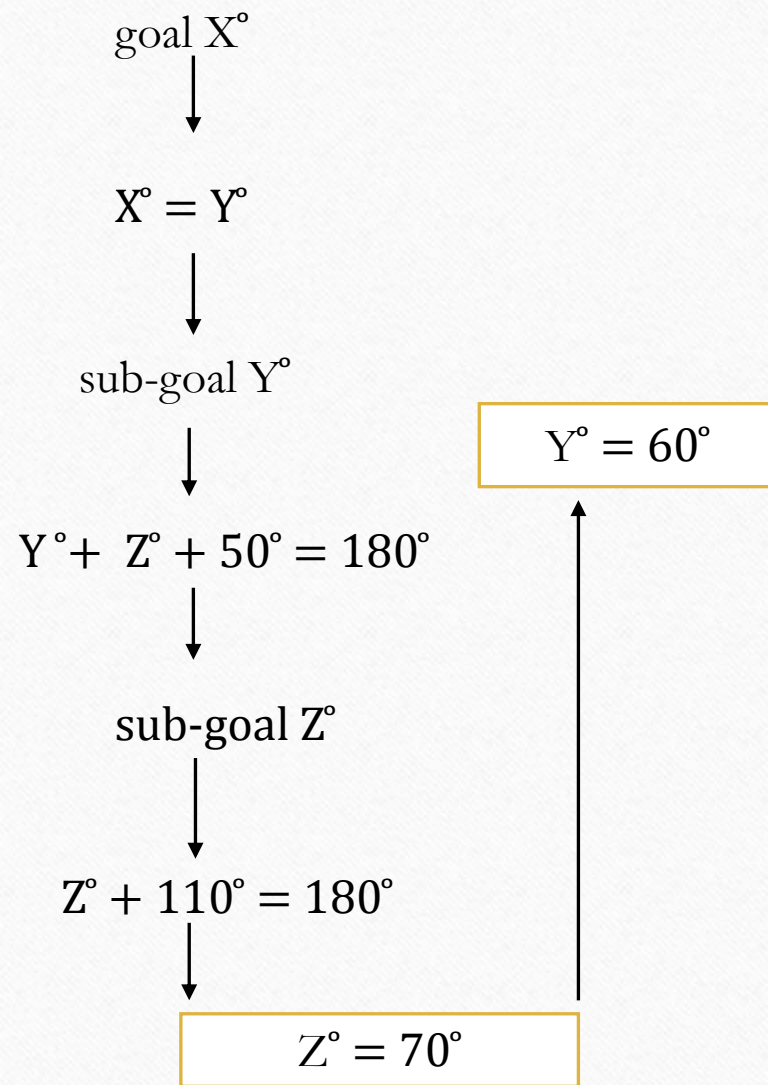
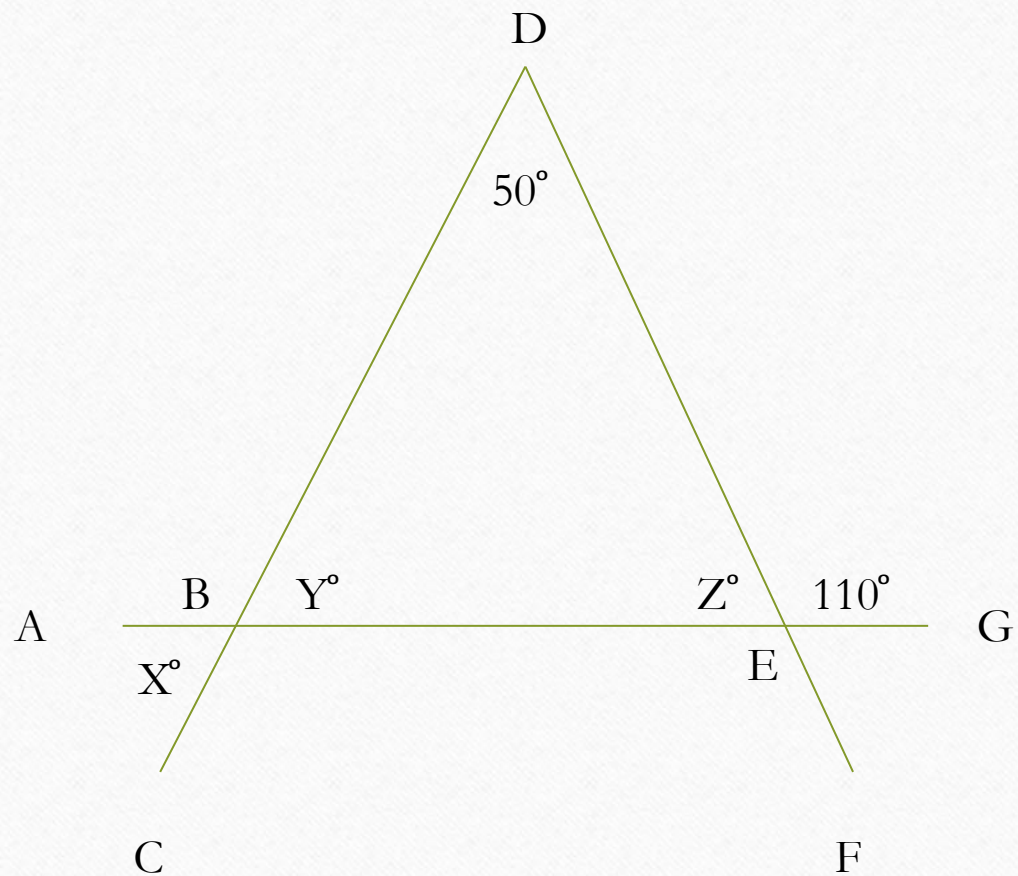
goal X°
↓
 $X^\circ = Y^\circ$
↓
sub-goal Y°
↓
 $Y^\circ + Z^\circ + 50^\circ = 180^\circ$
↓
sub-goal Z°

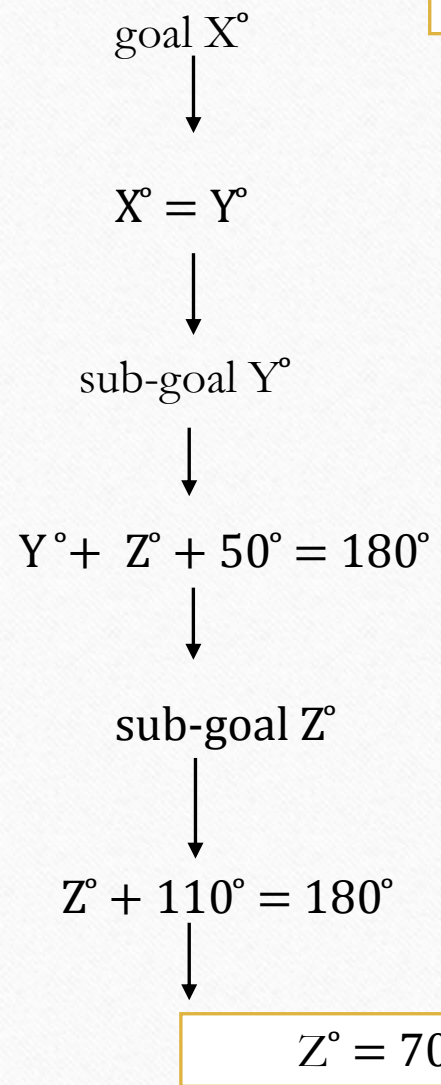
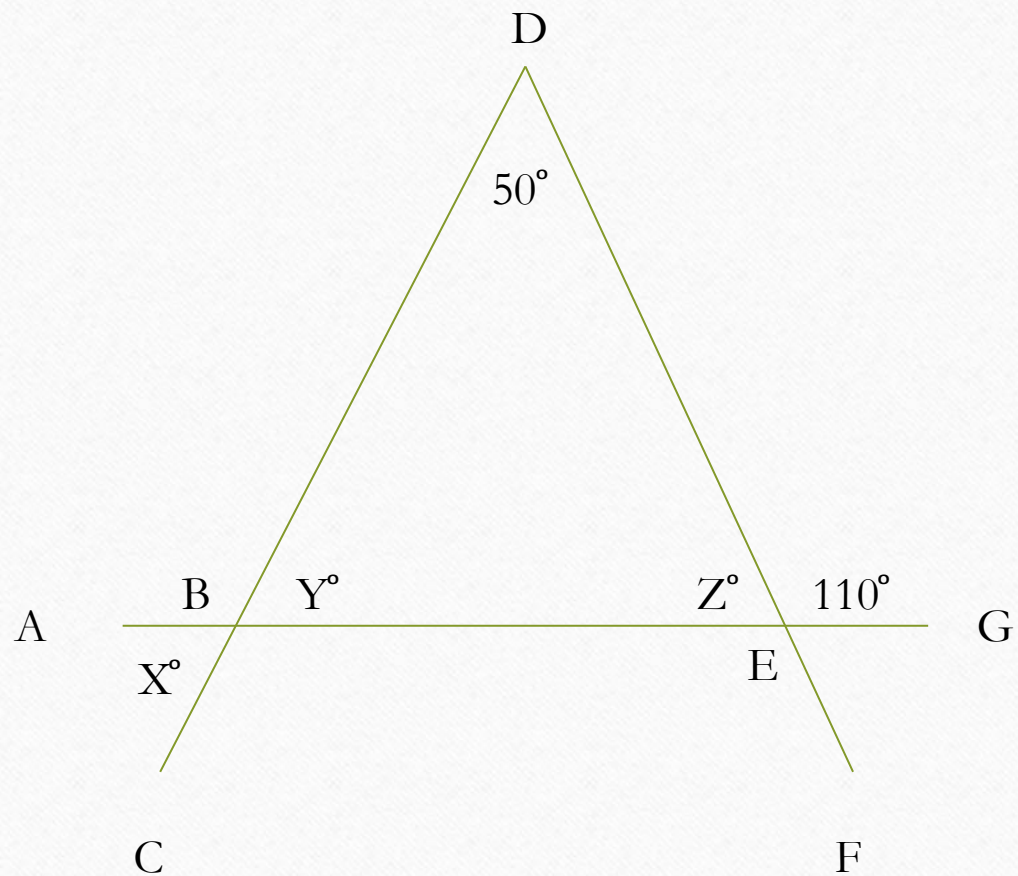


goal X°
↓
 $X^\circ = Y^\circ$
↓
sub-goal Y°
↓
 $Y^\circ + Z^\circ + 50^\circ = 180^\circ$
↓
sub-goal Z°
↓
 $Z^\circ + 110^\circ = 180^\circ$



goal X°
↓
 $X^\circ = Y^\circ$
↓
sub-goal Y°
↓
 $Y^\circ + Z^\circ + 50^\circ = 180^\circ$
↓
sub-goal Z°
↓
 $Z^\circ + 110^\circ = 180^\circ$
↓
 $Z^\circ = 70^\circ$





$$X = 60$$

$$Y = 60$$

$$Z = 70$$

Means-ends analysis places high demands on working memory and requires large amounts of cognitive resources.

Problem solvers using means-ends analysis may successfully solve many problems of any identical type, yet effectively learn nothing from the activity

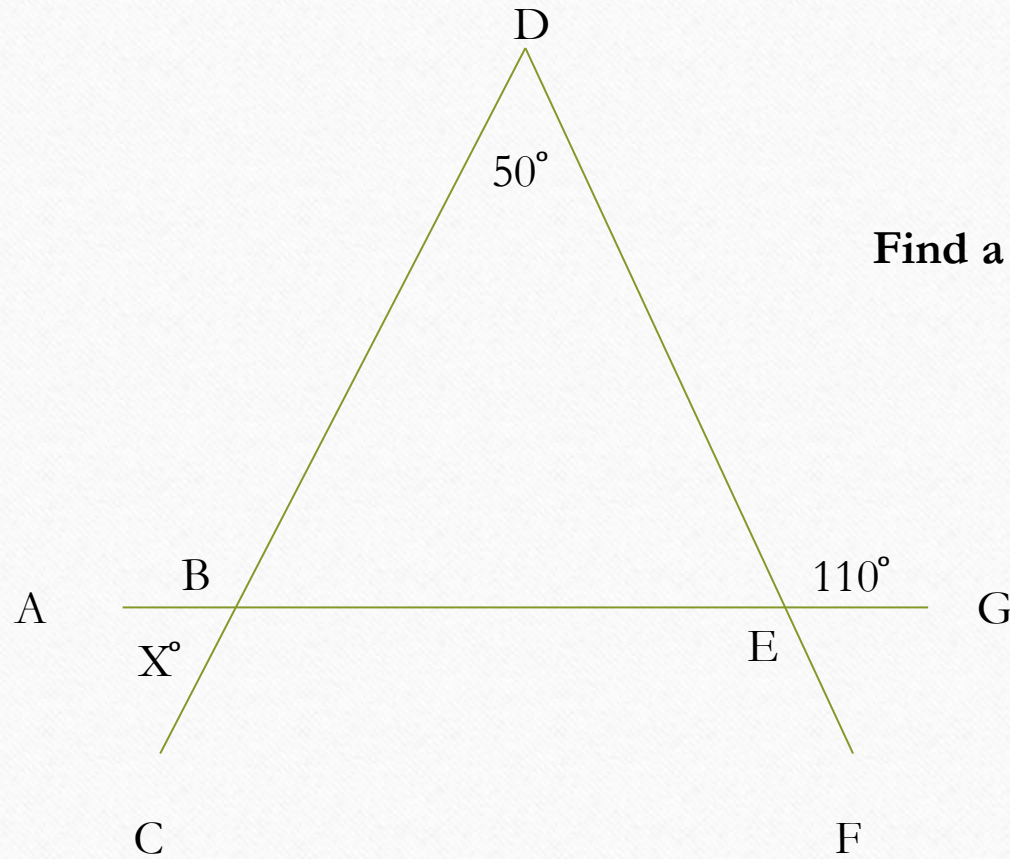
Problem solving search can inhibit learning leaving no cognitive resources available to construct schemas

Conventional problem-solving strategies are associated with a significant extraneous cognitive load that has to be eliminated or reduced in order to facilitate learning

HOW?

Extraneous cognitive load could be reduced when learners' cognitive activities are directed to problem states and their associated moves

Conventional Problem



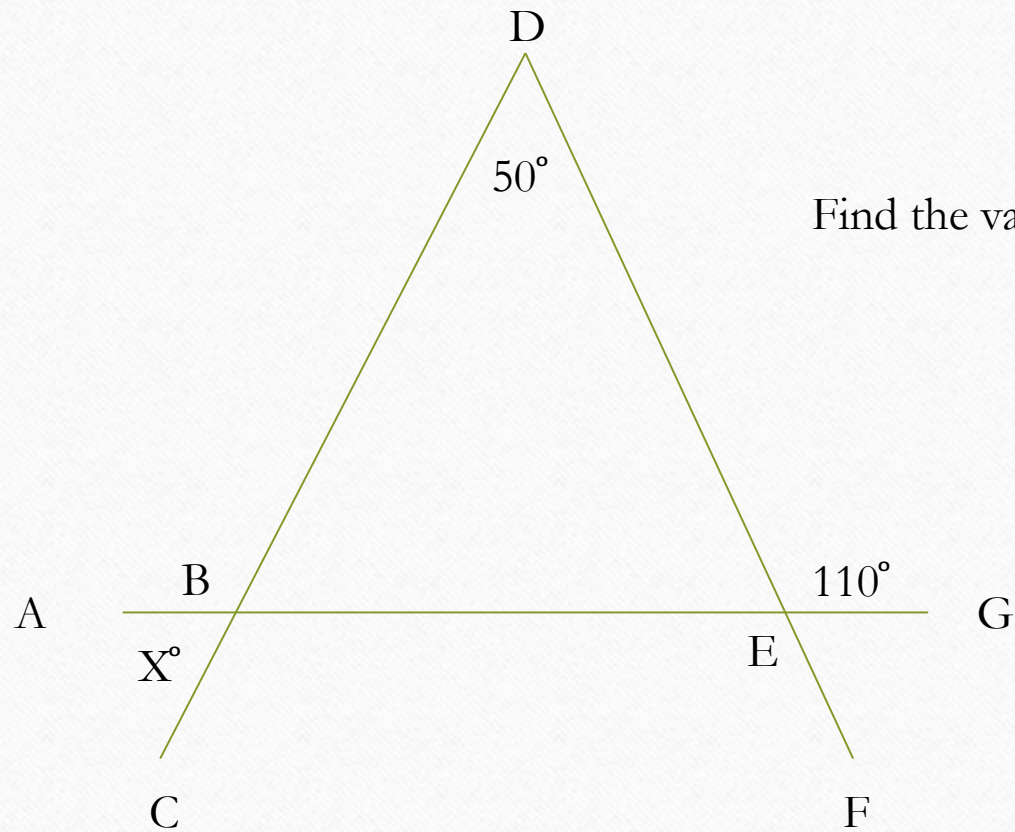
Find a value for angle X

Redefine the problem so that the learner moves in a forward working manner

The learner should concentrate on each problem state and corresponding move: there should be no activities irrelevant to schema acquisition

Redefine the problem so that no obvious goal exist

Goal-free problem



Find the values of as many as angles as possible

The goal free affect

Traditional problems:

Calculate the value of the parameter X .

Evidence: students continued to use the means-ends strategy on post-instruction test problems

Goal free (nonspecific goal) problems:

Calculate the values of as many parameters as you can

Evidence: students worked forward on post-instruction test problems: evidence of acquire schemas

Goal-free problems direct attention to those aspects of a problem that should assist in schema acquisition and automation

Learner moves in a forward working manner similar to that used by expert problem solvers

Forward working strategies impose low levels of cognitive load and facilitate learning

Limitations

- Goal-free technique may not be appropriate under conditions where a very large number of moves can be generated.
- Goal-free technique is affective for problems that have a limited search space. In areas of high search space worked examples could be used.

Worked examples:

- Consist of a problem statement (the givens of a problem) followed by all the appropriate solutions steps (including the final answer)
- Provide an expert problem solution for a learner, typically presenting solution in a step-by-step manner
- Example-problem pairs consist of a mixture of worked examples and pure problems
- Example-problem pairs could be more motivating than studying worked examples alone

Solve for: $\frac{2x-3}{2} = -4$

$$\frac{2x-3}{2} \boxed{*2} = 4 \boxed{*2}$$

$$2x-3 = 8$$

$$2x - 3 + 3 = 8 + 3$$

$$2x = 11$$

$$\frac{2x}{2} = \frac{11}{2}$$

$$x = \frac{11}{2}$$

Continue

Cooper and Sweller (1987)

Sweller and Cooper (1985)

$(a+b)/c = d$ Solve for a

$$a + b = dc$$

$$a = dc - b$$

Students attend to each line (problem state) and the algebraic rule (or move) needed for the transformation to the next line. As in the case for the goal-free problems, this activity corresponds closely to that required for schema acquisition.

Zhu and Simon (1987): a three year mathematics course was completed in 2 years by emphasizing worked examples rather than conventional instruction.

Worked examples

- Eliminate the need for learners to engage in unproductive problem solving strategies
- Studying worked examples requires the learner to attend only each problem state and its associated move.
- Learners acquire forward working procedures similar to those used by experts
- Especially useful in the initial stages of the instruction with materials that are difficult to learn

Performance on transfer problems

- Sweller & Cooper (1985) did not observe a significant difference in performance on transfer problems between worked example and problem solving groups.
- By simplifying the task and providing more example to study, they obtained better transfer for the worked examples group.
- **Extensive practice is required to automate basic problem-solving steps before any improvement can be observed for different problems. Automation frees up cognitive capacity, allowing learners to make appropriate generalizations.**
- **If transfer is an aim of instruction, an extensive mix of worked examples and actual problem solving could be the most effective instructional**

Limitations

- Worked examples may not be effective with learners who already acquired problem-solving schemas in the domain.
- When a worked example is structured in a way that produces high extraneous cognitive load the benefit is reduced.
- Some worked examples demonstrated performance no better than solving conventional problems

Tarmizi & Sweller (1988)

Cognitive load effects

Cognitive load effects	Primary cognitive load course
Goal-free	Extraneous
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Split-attention	Extraneous
Redundancy	Extraneous
Modality	Extraneous
Expertise Reversal	Extraneous
Guidance fading	Extraneous
Element Interactivity	Intrinsic
Isolated/interacting elements	Intrinsic
Imagination	Intrinsic

Split-Attention Effect. Integrated Instructions

Goal free and worked example effects:

Solving goal-free problems and studying worked examples require the learner to attend only to the problem state and its associated move.

Some worked examples demonstrated performance no better than solving conventional problems.

Tarmizi & Sweller (1988)

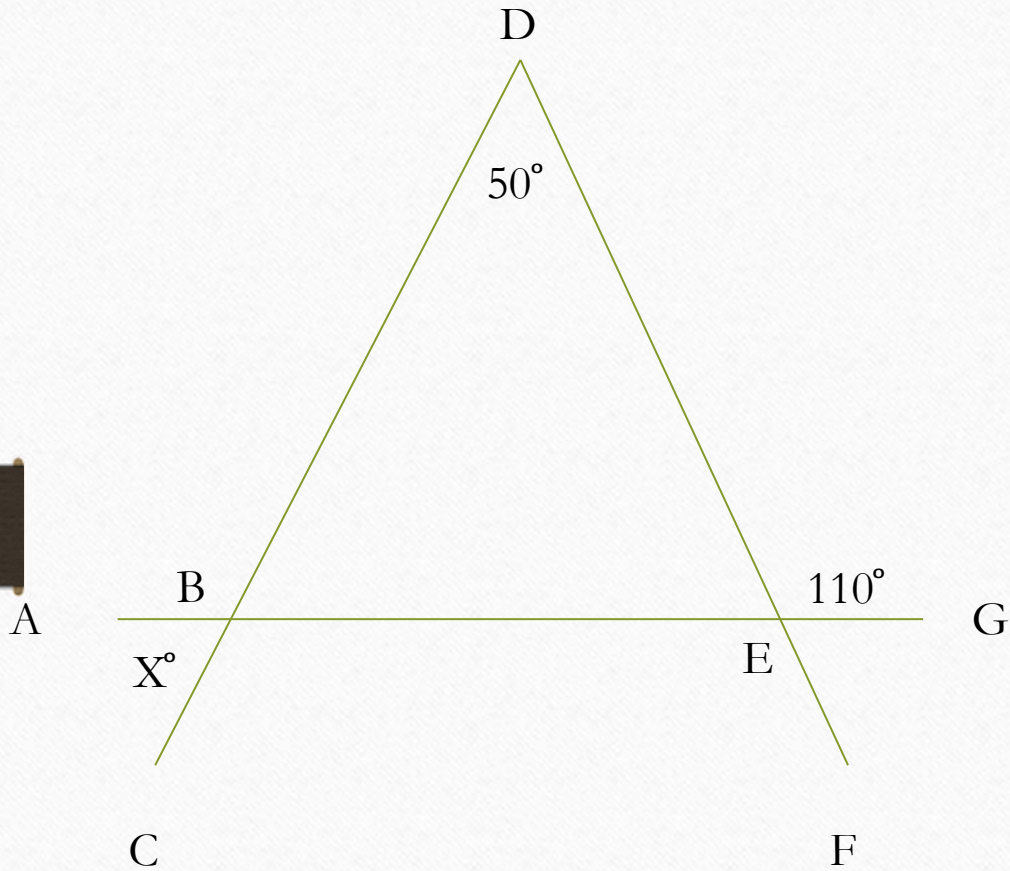
In some situations, worked examples may require significant cognitive resources to be processed.

Suggestions?

Restructuring examples:

Breaking down explanations of complex procedures into smaller elements.

What if smaller explanatory modules still impose significant cognitive load?



Procedure for finding Angle X:

Angle DBE = Angle DEG - Angle BDE (external angles for a triangle equal the sum of the opposite internal angles)

$$= 110^\circ - 50^\circ$$

$$= 60^\circ$$

Angle X = Angle DBE (vertically opposite angles are equal)

$$= 60^\circ$$

Geometry problems:

- Diagrams accompanied by brief textual statements
- Neither text nor diagrams are intelligible in isolation
- Understanding requires mental integration of text and diagrams

Split attention: searching and matching elements from the text to the appropriate entities on the diagram.

Solution?

Physically integrating textual information with the related diagram

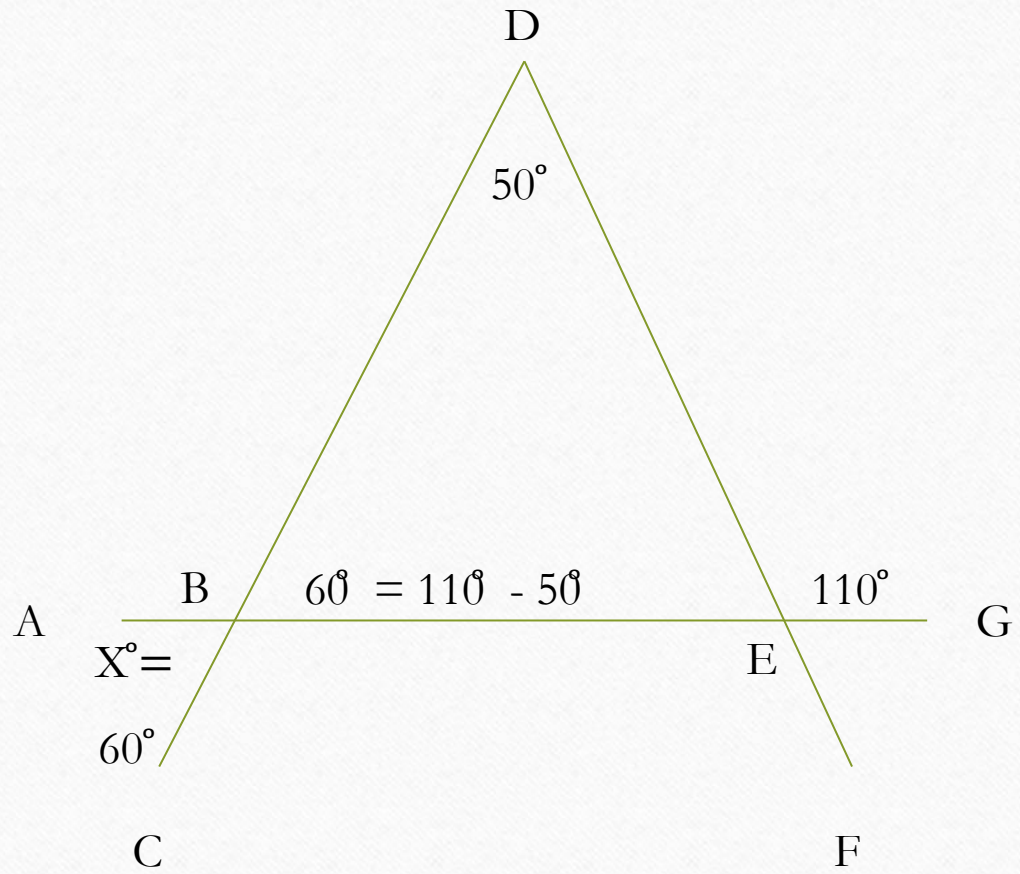
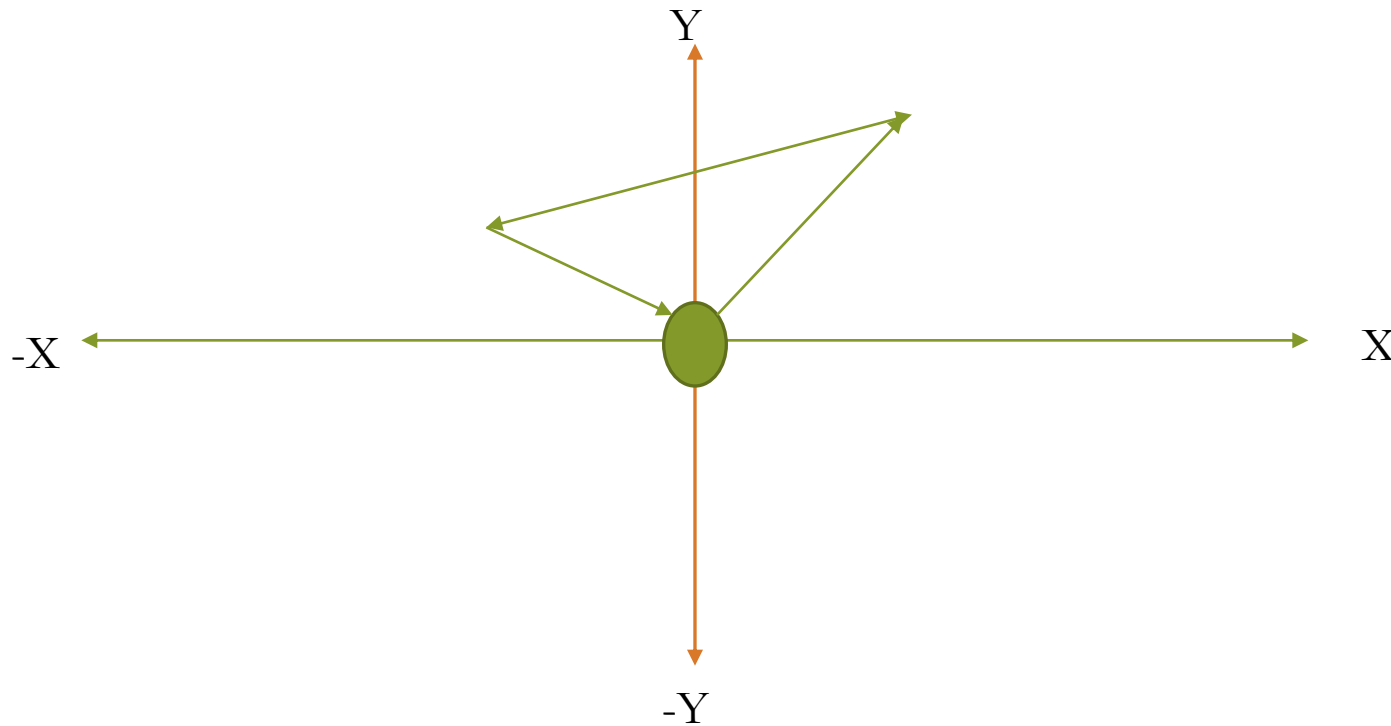


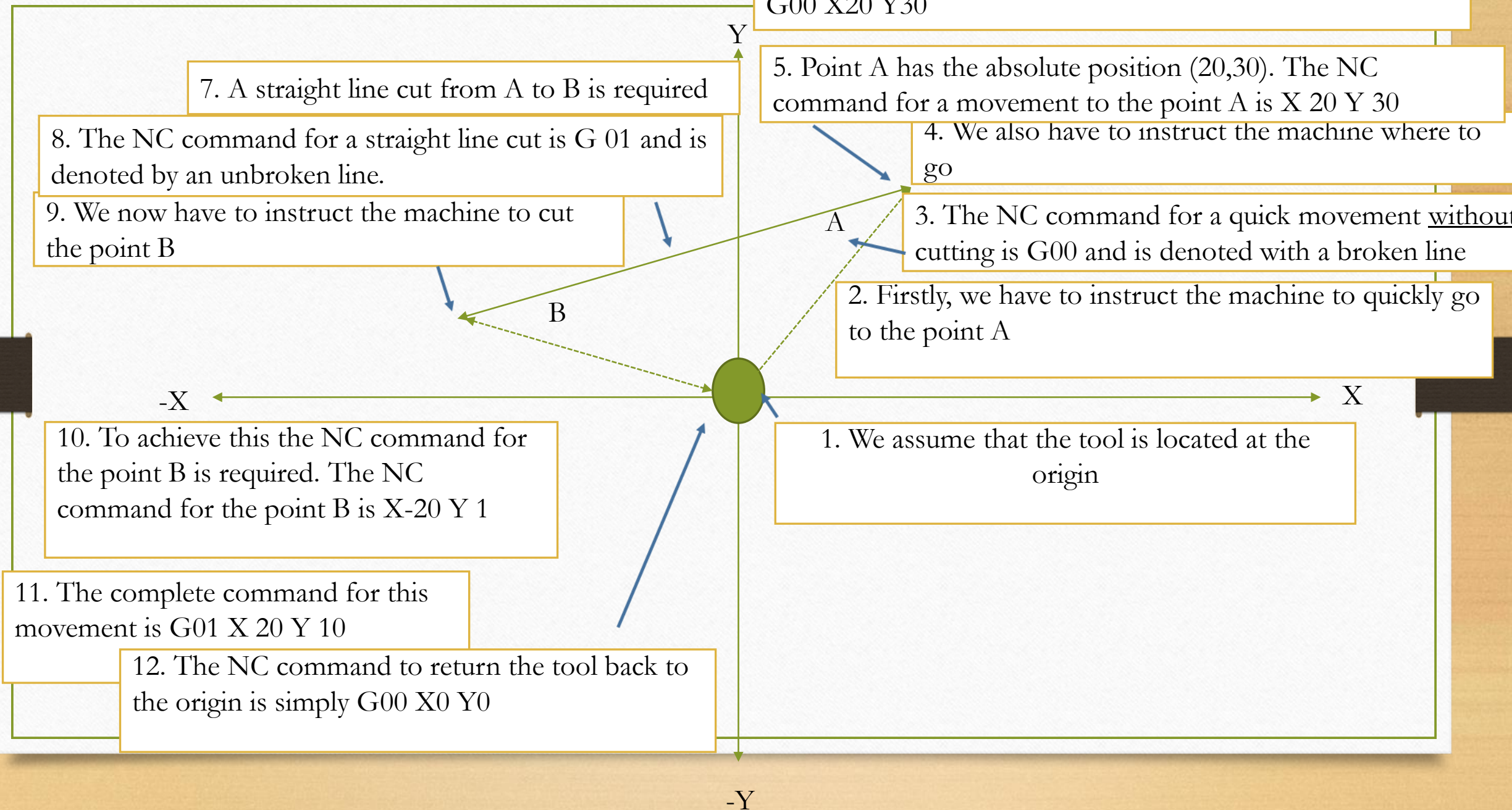
Figure 2. integrated geometry problem and solution.

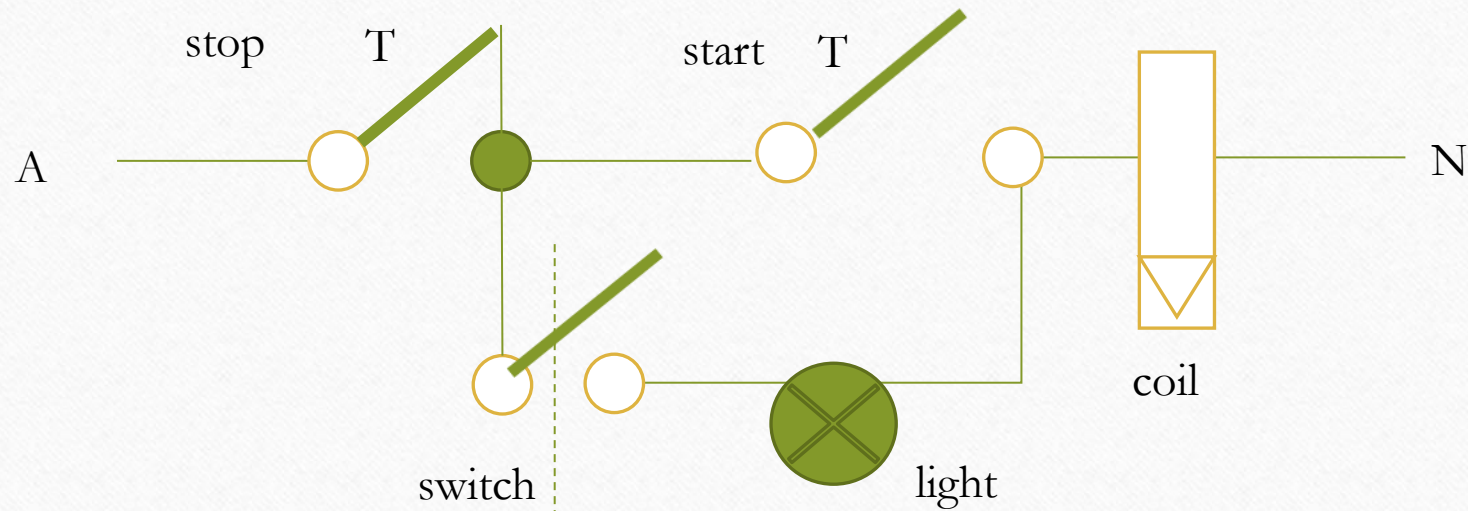
We assume that the tool is located at the origin. Firstly, we have to instruct the machine to quickly go to the point A. The NC command for a quick movement *without* cutting is G00 and is denoted with a broken line. We also have to instruct the machine where to go. Point A has the absolute position (20,30). The NC command for a movement to the point A is **X 20 Y30**. A straight line cut from A to B is required. The NC command for a straight line cut is **G01** and is denoted by an unbroken line. We know we have to instruct the machine to cut to point B. To achieve this the NC command for the point B is required. The NC command for point B is **X-20 Y 10**. The complete command for this movement is **G01 X-20**. The NC command to return the tool back to the origin is simply G00 X0 Y0 . This completes the NC program code for this job.



Split attention situation: learners have to mentally integrate multiple sources of information and this integration overburdens limited working memory capacity.

Follow the numbered steps

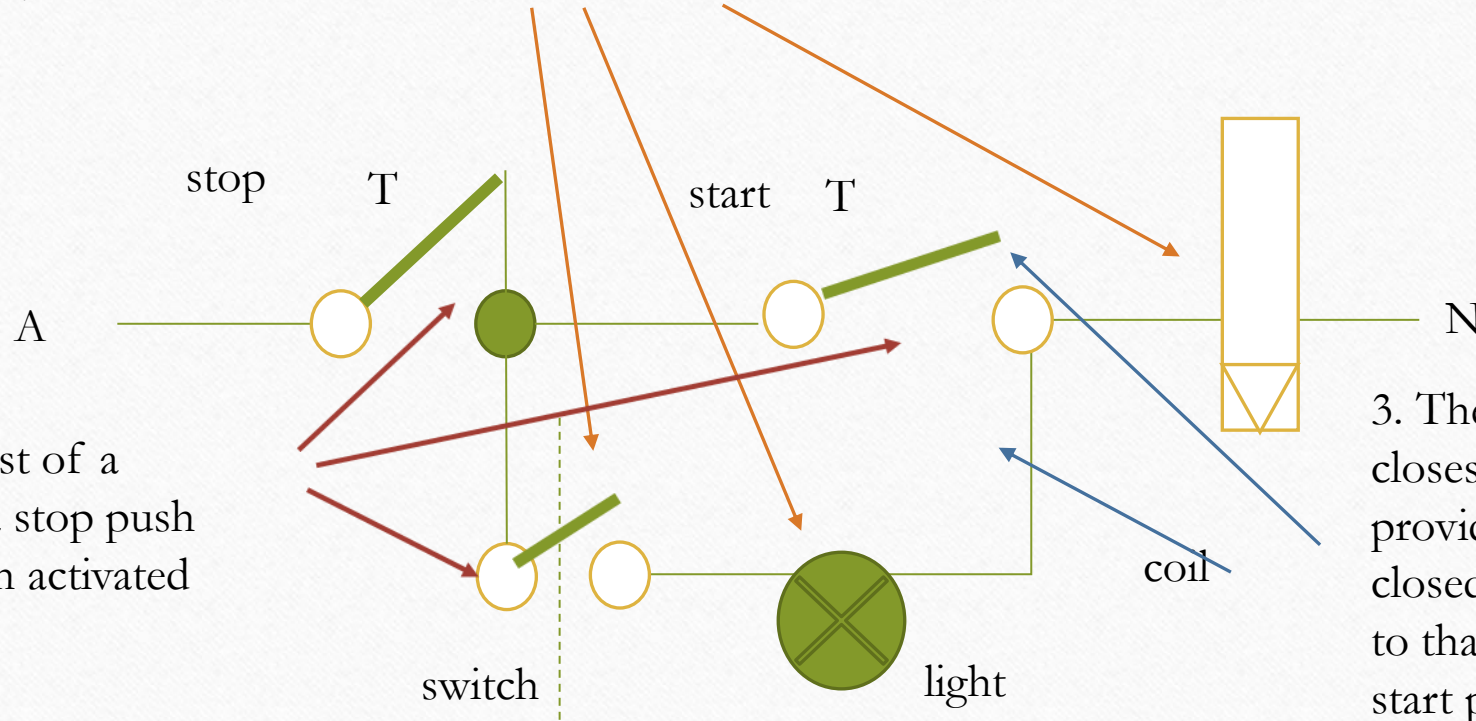




1. The Starter consist of a start push button , a stop push button, and a switch activated by the coil.
2. Pressing down the start push button closes the circuit and allows the current to flow through the coil.
3. The energizer coil closes the switch, which provides an alternative closed circuit for the coil to that provided by the start push button. The start push button now can be released without breaking the current flow through the coil.
4. The light is operational, as the closed switch provides a closed circuit for it.
5. To case operation of the light the stop push button is pressed. The circuit in the Starter is now open, the coil is no longer energized, and the switch returns to its normal open position.

5. To cease operation of the light the top push button is pressed. The circuit in the Starter is now open, the coil is no longer energized, and the switch returns to its normal open position.

2. Pressing down the start push button closes the circuit and allows the current to flow through the coil



1. The starter consists of a start push button, a stop push button, and a switch activated by the coil.

3. The energized coil closes the switch, which provides an alternative closed circuit for the coil to that provided by the start push button. The start push button can now be released without breaking the current flow through the coil.

4. The light is operational, as the closed switch provides a closed circuit for it.

Ward & Sweller, 1990:

A car moving from rest reaches a speed of 20 m/s after 10 second. What is the acceleration of the car?

$$u = 0 \text{ m/s}$$

$$v = 20 \text{ m/s}$$

$$t = 10 \text{ s}$$

$$v = u + at$$

$$a = (v-u)/t$$

$$a = (20 - 0)/10$$

$$a = 2 \text{ m/s}^2$$

A car moving from rest (u) reaches a speed of 20 m/s (v) after 10 second (t):

$$[v = u + at, a = (v-u)/t = (20-0)/10 = 2 \text{ m/s}^2].$$

What is the acceleration of the car?

Example of integrated condition

Then out slithered the rest of his long thin body. He twisted and turned on the slippery bottom of the bath, spitting and hissing at us.

Example of Separated condition

Then out slithered the rest of his long thin body. He twisted and turned on the slippery bottom of the bath, spitting and hissing at us.

Slithered

Twisted

Slippery

Spitting

hissing

The Integrated Format

a) Examples of the vocabulary condition:

It never thinks of roaming unless it fears that there is a drought at hand. Since it doesn't want to be stranded, it sets out to look for a deeper pool of water.

b) Examples of the commentary condition:

It never thinks of roaming unless it fears that there is a drought at hand. Since it doesn't want to be stranded, it sets out to look for a deeper pool of water.

c)) Examples of the Combined condition:

It never thinks of roaming unless it fears that there is a drought at hand. Since it doesn't want to be stranded, it sets out to look for a deeper pool of water.

Split attention effect: physically integrating corresponding sources of information within instruction may reduce extraneous cognitive load

Integrated instructional formats are beneficial for learning if:

- The sources of mutually referring information need to be mentally integrated in order to be understood;
- The information is characterized by high element interactivity

Multiple representations (text, pictures, video, etc.) may cause split attention.

Internet may place greater cognitive demands on students.

Reading could be more difficult in a nonlinear “hypertext” environment: several shorter text should be integrated and reconciled.

Instructional design implications:

Integrate the text into the graphic

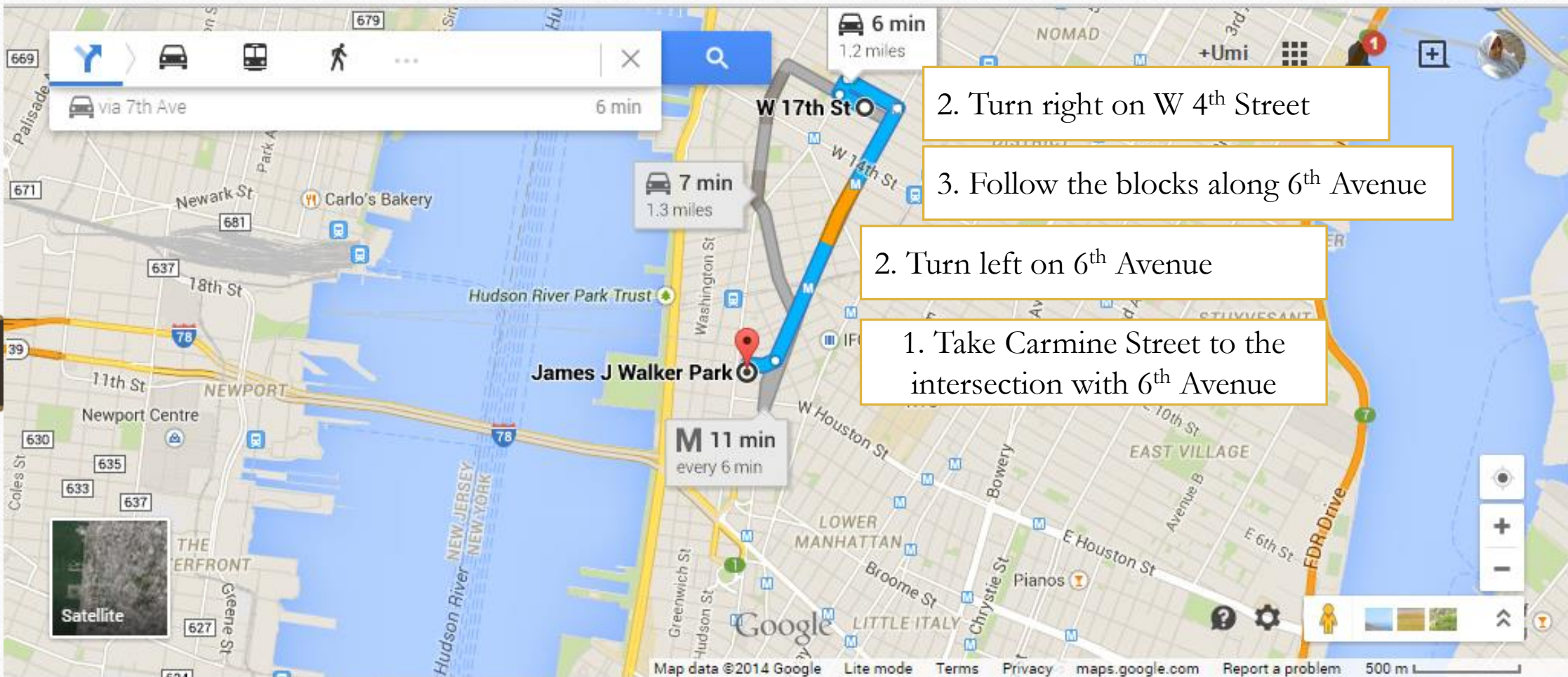
Avoid covering or separating information that must be integrated for learning

Design space for guidance or feedback close to problem statements, both being visible

Instructional design implications:

- **Integrate the text into the graphic**
- **Avoid covering or separating information that must be integrated for learning**
- **Design space for guidance for feedback close to problem statements, both being visible**

Redundancy effect



2. Turn right on W 4th Street

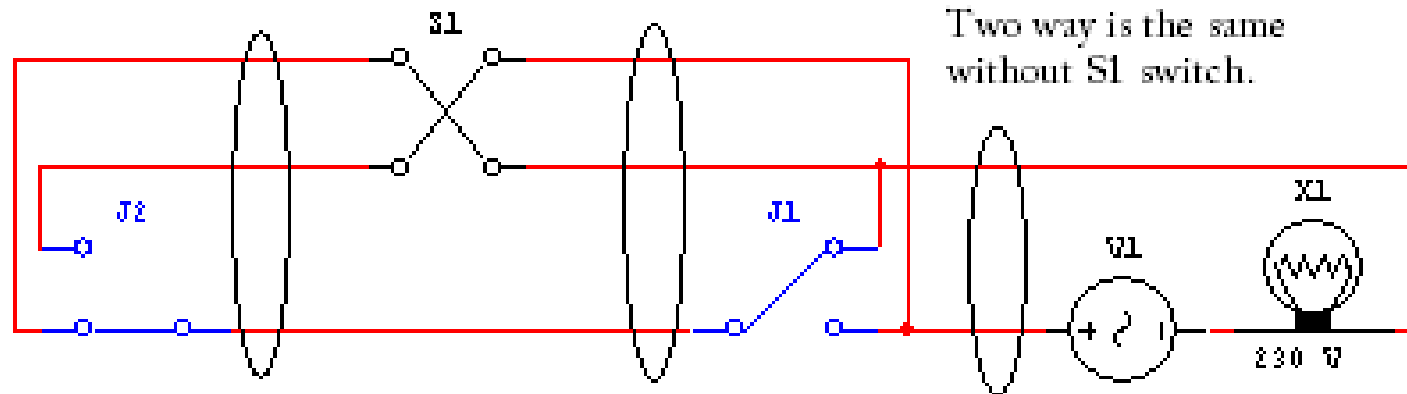
3. Follow the blocks along 6th Avenue

2. Turn left on 6th Avenue

1. Take Carmine Street to the intersection with 6th Avenue

Redundancy effect: if a source of information (textual or graphical) is fully intelligible on its own, then any additional redundant sources of information should be removed from the instructional materials rather than integrated into it (e.g. maps, street directories, pie-charts)

Internal wiring for intermediate switching

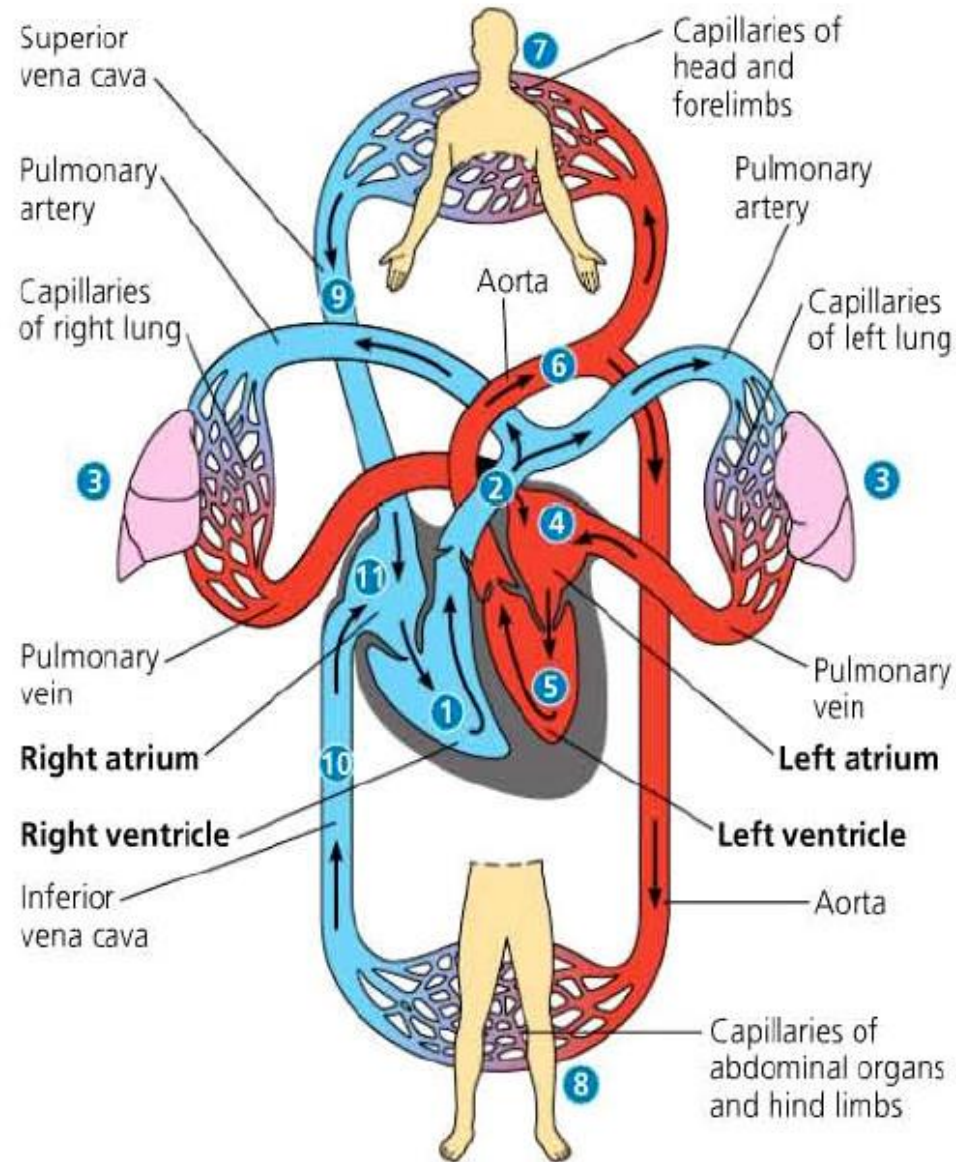


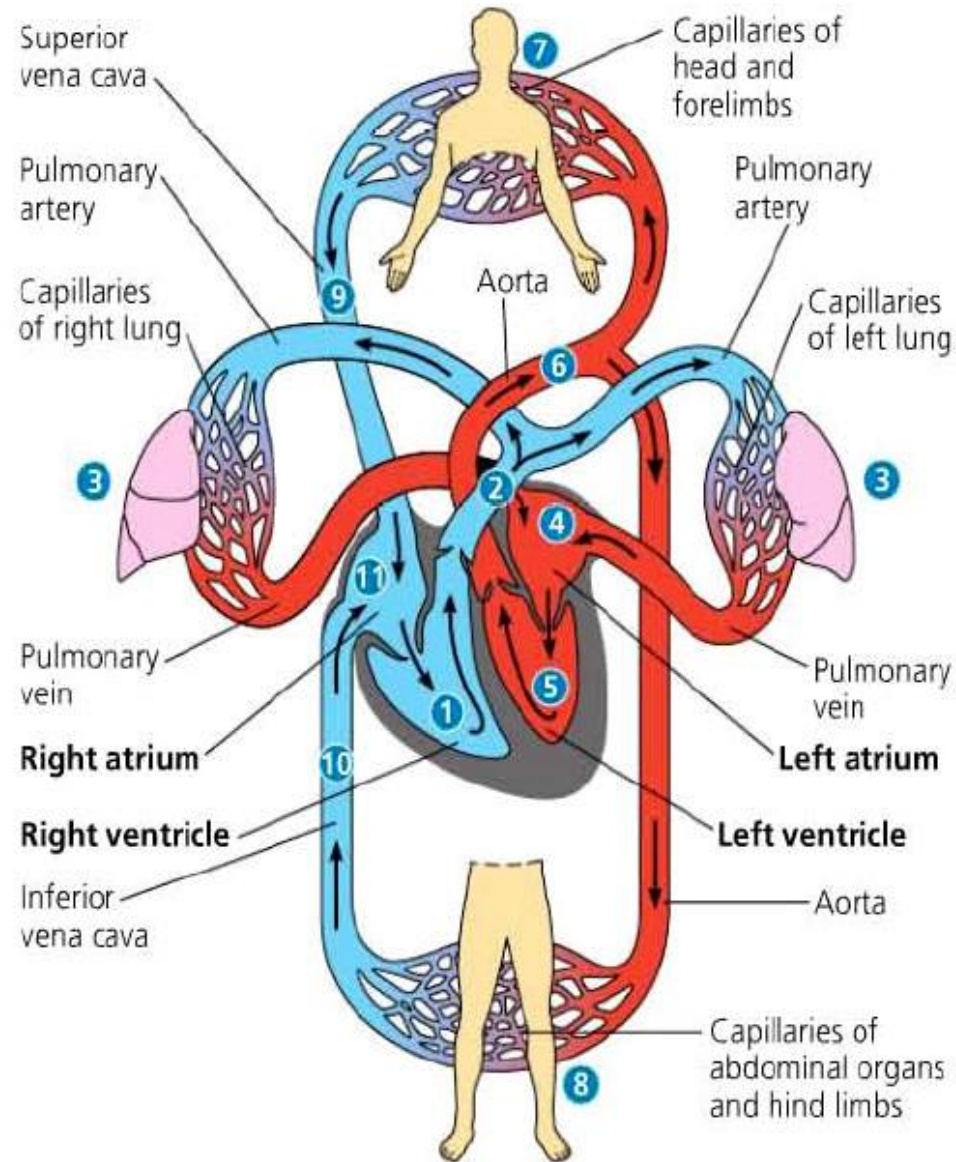
Two way is the same without S1 switch.

The three ellipses show the cables between switches. Earths are not shown for clarity. for wire between J1 and J2 a block connector is used. But no connector is required in J1 or J2.

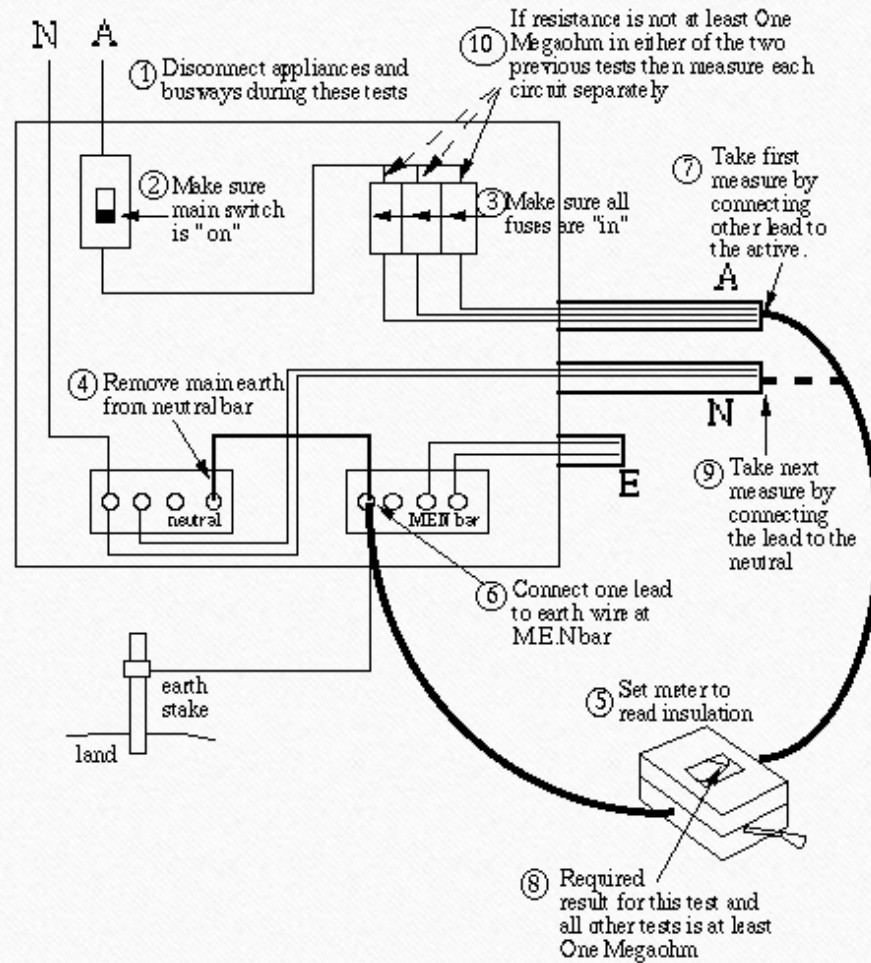
230 V
50 Hz
0Deg

As seen the neutral does not go to switches.

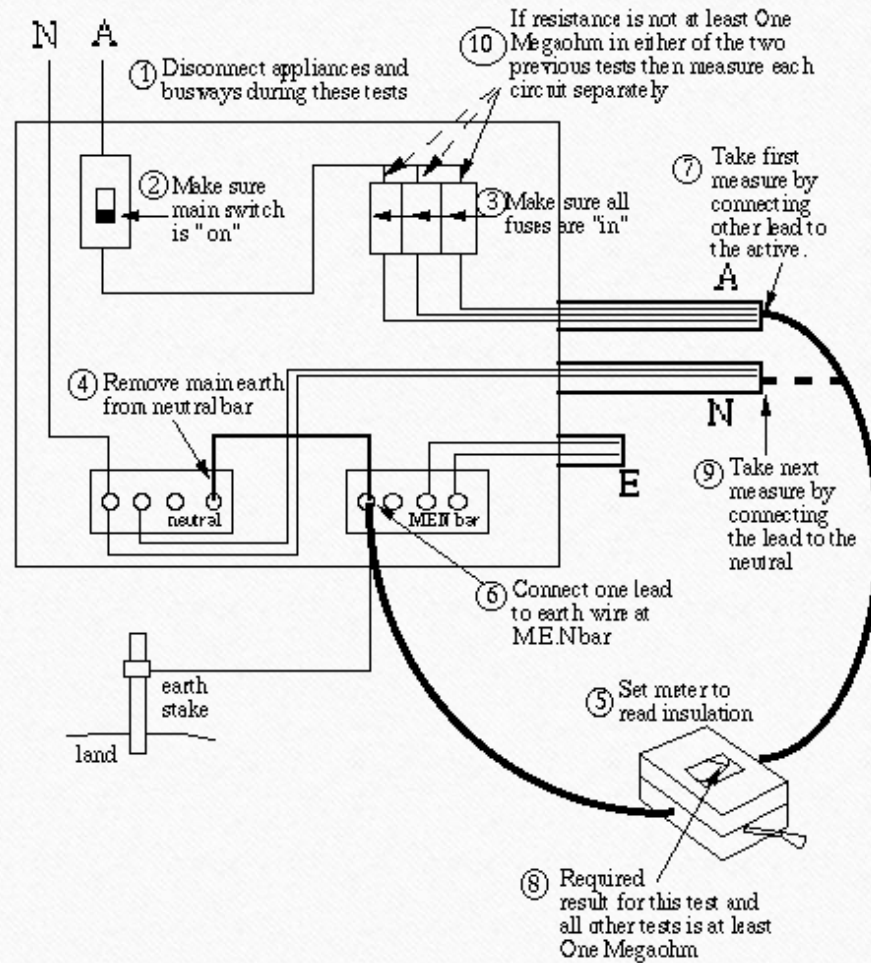




INSULATION RESISTANCE TESTS CONDUCTOR IN PERMANENT WIRING



INSULATION RESISTANCE TESTS CONDUCTOR IN PERMANENT WIRING



Sweller & Chandler, 1994; Chandler & Sweller, 1996:

- Integrated manual plus hardware group
- Conventional manual plus hardware group
- Integrated manual plus hardware group

Significant differences between the groups in both written and practical skills: the hardware (e.g. computer or lab equipment) appeared to be redundant.

Studying computer packages, software manuals (word processing, spreadsheet packages, etc)

Mentally integrating information from the manual, screen, and keyboard.

Split- attention and redundancy situations?

Cognitive load theory recommendations:

- Eliminate the computer during the initial instructional period
- Replace computer with diagrammatic representations of the screen and keyboard
- Integrate segments of textual instructions at their appropriate locations in the diagrams

When instructional materials are demanding (with high intrinsic load), the **temporary elimination of the hardware** may facilitate learning and reduce instruction time.

Alternatively, elimination of the manual and **placing everything on the screen** (computer based training) may also be effective

However, in areas where motor components and spatial-motor coordination are essential (e.g., typing or driving a car), extensive practice with real equipment from the beginning is always important.

Reder and Anderson (1980): students could learn more from summaries of textbooks than from the full chapter.

Miller (1937): presenting children a word associated with a picture was less effective in teaching children to read than the word alone.

Lesh, Behr, and Post (1987): mathematical word problems become more difficult with additional information in the form of concrete materials.

Design implications:

Avoid redundant and irrelevant graphics, stories, and lengthy text

No split-attention and redundancy effects were demonstrated in areas of low element interactivity

Repetition is not redundancy

Distinction between the split- attention and redundancy effects:

- Integrate, if sources of information are unintelligible in isolation
- Eliminate, if sources of information are intelligible in isolation.

However, intelligibility always depends on the level of learner prior knowledge

Expertise reversal effect (to follow later)