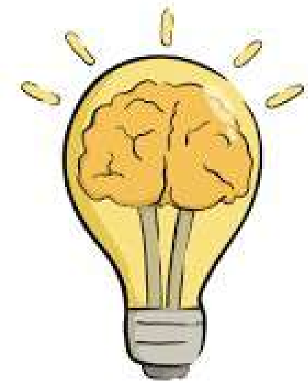
Aligner l’enseignement des mathématiques sur la science de l’apprentissage

Animatrice : Carla French

Les notes de l’animatrice se trouvent dans la section « Notes » sous chaque diapositive.

Grandes idées de la session:



Qu’est-ce que la science de l’apprentissage ?

Nous examinerons trois approches fondées sur la recherche :

1. La théorie de la charge cognitive
2. L’enseignement explicite
3. Les principes d’instruction de Rosenshine

-Comment appliquer ces principes à la planification et à l’enseignement des mathématiques?

Qui suis-je ?

Carla French
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YouTube: LoveMath2 with Carla French

- Diplôme en commerce, baccalauréat en éducation, maîtrise interdisciplinaire + pédagogie des maths
- Analyste dans le secteur de pétrole
- Learning Leader junior high maths – enseignante 3e à 8e
- Instructrice à l'Université de l'Alberta, Campus St Jean, Calgary.
- Maman.

Qu’est-ce que c’est la science de l’apprentissage?

- Comment apprenons-nous ?
- BUT: Comment enseigner pour optimiser l'apprentissage ?

https://www.jamieleeclark.com/blog/one-pagers

« La cognition est le terme que nous utilisons pour désigner les activités mentales telles que voir, participer, se souvenir et résoudre des problèmes » (CogniFit Research, s.d.).

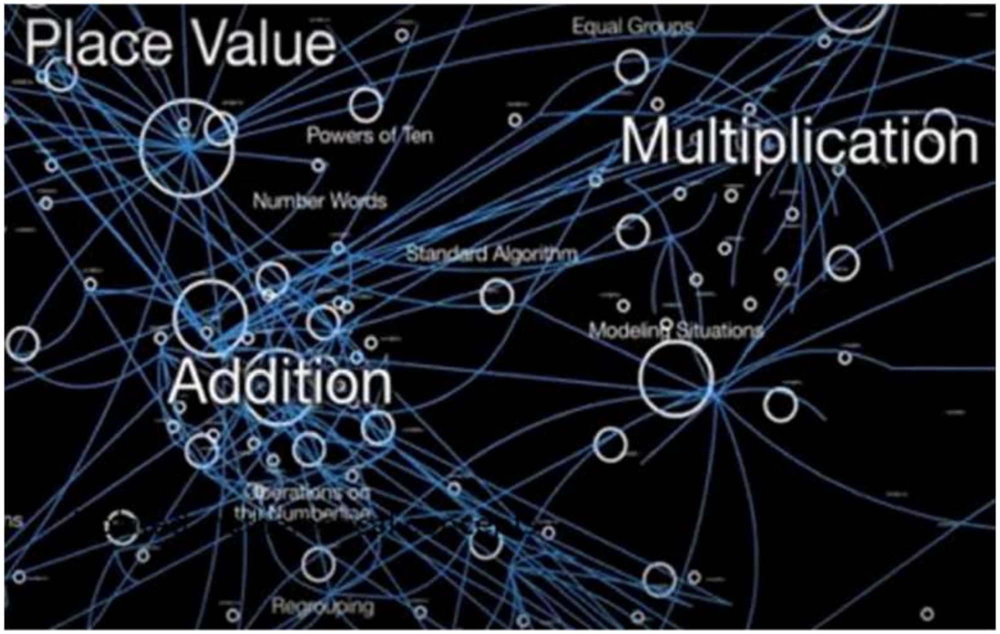
La théorie de la charge cognitive (TCC) explore comment la charge cognitive, ou l'effort mental, nécessaire au traitement de l'information influe sur l'apprentissage.

Notre mémoire à long terme contient des schémas

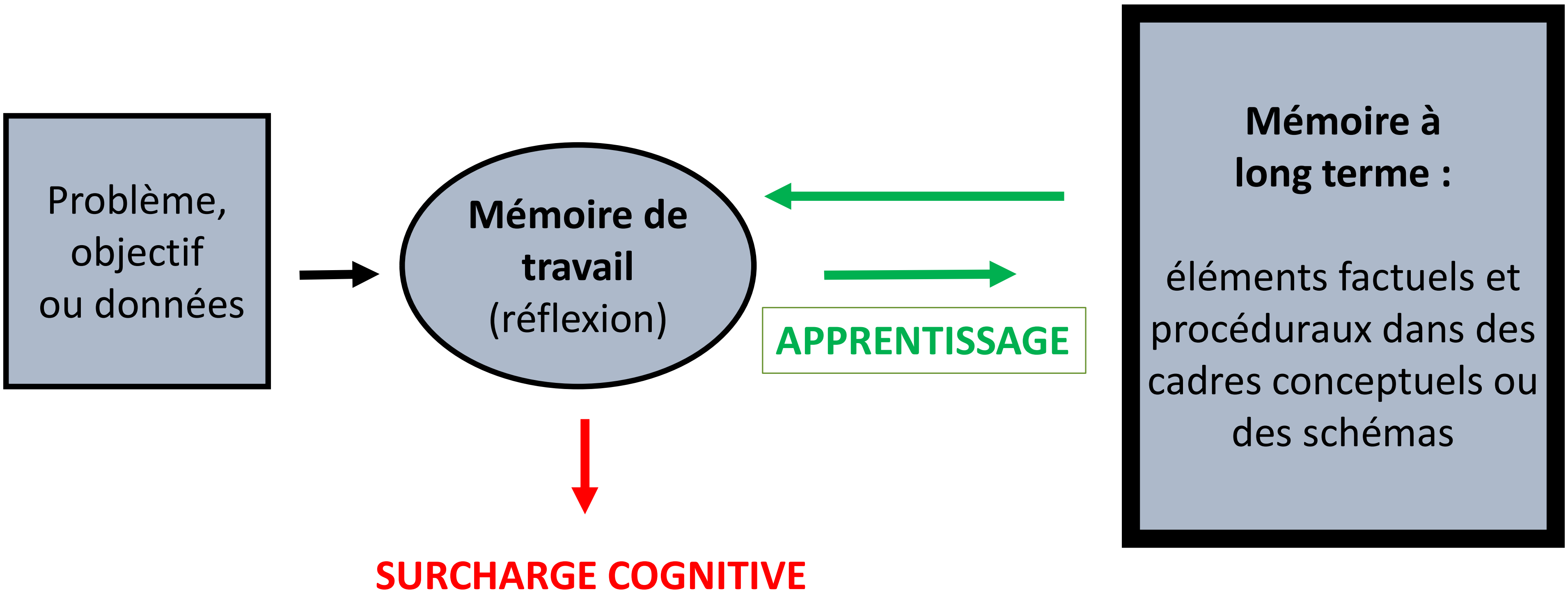
Les schémas sont des réseaux de connaissances interconnectés dans le mémoire à long terme.

Un ***expert*** dispose de vastes réseaux de connaissances interconnectés.

Un ***novice*** dispose de réseaux déconnectés avec des connaissances limitées.



Comment le cerveau résout-il les problèmes ?



Adapté de Hartman et al.

RÉDUIRE LA CHARGE EXTRINSÈQUE ET OPTIMISER LA CHARGE INTRINSÈQUE

Charge intrinsèque:

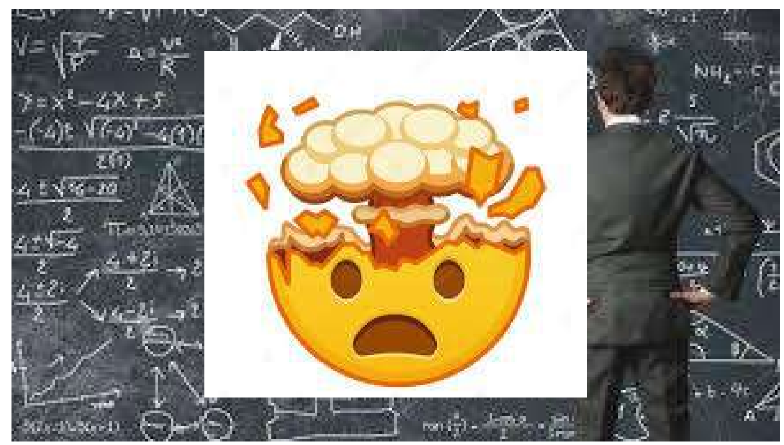
La difficulté propre au contenu à apprendre.

Elle dépend de :

- La *complexité* de la matière
- Les *connaissances antérieures* de l'élève

$$f'(x)=\lim_{h\to 0}\frac{f(x+h)-f(x)}{h}$$

2 + 2 =



Charge extrinsèque :

L'effort inutile causé par la manière dont l'information est présentée. Résulte souvent d'une mauvaise conception pédagogique.

L'ENSEIGNEMENT EXPLICITE - *aller du plus simple vers le plus complexe!*

	Etape	Détail
	L'ouverture	L'enseignant expose les objectifs et présente quelques rappels.
Je fais	Le modelage	L'enseignant présente seul et de manière explicite, la méthode permettant de réaliser la tâche.
Nous faisons	La pratique guidée	Les élèves réalisent à leur tour la tâche, guidés par l'enseignant.
Tu fais	La pratique autonome	Les élèves réalisent seuls la tâche.
	La clôture	Une synthèse est réalisée, avec une ouverture possible sur la séance suivante.

https://pia.ac-paris.fr/portail/jcms/p1_3101238/enseignement-explicite

EXPLICIT INSTRUCTION

DIRECT & ENGAGING TEACHING

EXPLICIT INSTRUCTION
EFFECTIVE & EFFICIENT TEACHING

Les leçons interactives rendent l'apprentissage visible afin que les enseignants puissent s'assurer que les élèves apprennent.

ANITA ARCHER & CHARLES HUGHES

DELIVERING INSTRUCTION

COMPÉTENCES EN MATIÈRE D'ENSEIGNEMENT EXPLICITE
L'attention et l'apprentissage des élèves dépendent à la fois de la conception et de l'exécution d'une leçon explicite. Pour être vraiment efficace, l'enseignement doit être interactif.

COMPÉTENCES ESSENTIELLES
- Exiger des réponses fréquentes
- Contrôler les performances de l'élève
- Feedback correctif immédiat
- Dispenser les cours à un rythme soutenu

INPUT →	QUESTION →	RESPONSE →	MONITOR →	FEEDBACK
présenter les informations par petits blocs	l'enseignement interactif - donner du temps de réflexion	susciter une réponse à l'unisson	circuler dans la salle et vérifier la compréhension	la rendre affirmative et corrective

LESSON OPENING

PREVIEW

Énoncer l'objectif de la leçon et discuter de la pertinence de la compétence cible

REVIEW

Revoir les compétences préalables essentielles requises

DEMONSTRATE UNDERSTANDING

LESSON BODY

MODELLING
I do it

MONTRER ET RACONTER
Démontrer la compétence et décrire ce qui est fait en utilisant plusieurs modèles différents.

PENSEZ À L'ÉCOUTE
Utilisez systématiquement un langage pertinent et décrivez uniquement les actions clés.

DEMONSTRATE UNDERSTANDING

GUIDED PRACTICE
We do it

RÉDUIRE L'INCITATION
Incitations physiques, verbales et visuelles.

RÉDUIRE L'ÉCHAFAUDAGE
Dire aux élèves ce qu'ils doivent faire
Demander aux élèves ce qu'ils doivent faire
Leur rappeler ce qu'ils doivent faire

DEMONSTRATE UNDERSTANDING
HIGH RATES OF ACCURACY

UNPROMPTED PRACTICE
You do it

Les élèves s'exercent sans être guidés par l'enseignant :

-Présenter des problèmes ou des tâches similaires
-Les élèves complètent un élément à la fois
-Vérifier les réponses et fournir un retour d'information après chaque élément

DEMONSTRATE UNDERSTANDING
HIGH RATES OF ACCURACY

LESSON CLOSING

REVIEW

Impliquer les étudiants dans la révision du contenu critique couvert

PREVIEW

Prévisualiser le contenu de la prochaine leçon

ASSIGN

Assigner un travail indépendant si les élèves en sont au bon stade.

THROUGHOUT THE LESSON: INVOLVE STUDENTS. MONITOR PERFORMANCE. PROVIDE FEEDBACK.

INDEPENDENT PRACTICE

DÉVELOPPER LA FLUIDITÉ
La recherche montre que pour atteindre la compétence, la pratique et le retour d'information sur la qualité de cette pratique sont nécessaires. Concentrez-vous sur les compétences, les concepts et les règles qui sont inconnus des élèves et qui sont essentiels à leurs résultats scolaires. Intégrez des séances de pratique délibérée dans vos cours, répartissez les séances de pratique d'une compétence dans le temps et testez les connaissances avec des tâches de récupération fréquentes.

DELIBERATE PRACTICE

garantir des niveaux élevés de précision, puis mettre en place une pratique de masse immédiate

DISTRIBUTED PRACTICE

espacement de courtes séances de pratique d'une compétence au fil du temps

RETRIEVAL PRACTICE

tester les connaissances dans des conditions à faible enjeu et mélanger les stratégies

SUSCITER DES RÉPONSES FRÉQUENTES
La participation active vise à impliquer tous les élèves en leur donnant la possibilité de réagir de manière structurée, que ce soit par la parole, l'écrit ou l'action. En répondant, les élèves récupèrent, répètent et mettent en pratique les informations, les concepts, les compétences ou les stratégies enseignés. Susciter des réponses, en présentant quelques informations avant de s'arrêter pour demander une réponse - cela permet de responsabiliser les élèves.

ACTION RESPONSES

Hand Signals *put up number of fingers for answer*
Acting Out *physically show solid, liquid, gas*
Gestures

WRITTEN RESPONSES

Mini-whiteboards
Response Cards *yes/no, T/F*
Hinge Questions
Exit Tickets
Written Summary

ORAL RESPONSES

Choral Response *everyone say it together in unison*
Think, Pair, Share
Cold Calling
Random Name Generator

Designed by **JAMIE CLARK** | XpatEducator

Reference: 'Cognitive Load Theory: Research That Teachers Really Need To Understand: Classroom Practice Guide'.
Centre For Education Statistics and Evaluation, 2017.

John Sweller et al.

Cognitive Load Theory

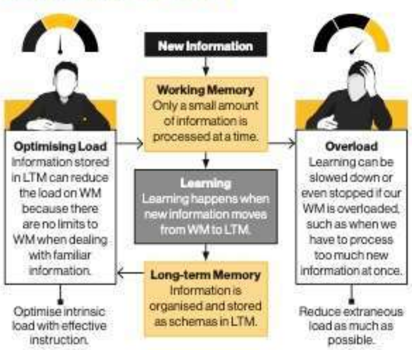
Six Strategies to Tailor Instruction for Maximum Learning

Sweller's Cognitive Load Theory

Tailoring Instruction for Maximum Learning

Cognitive Load Theory (CLT) explores how the cognitive load, or mental effort, required to process information impacts learning. To learn something new, knowledge must first be processed in working memory (WM) before being transferred and stored in long- term memory (LTM) in the form of 'schemas'. If WM is overloaded, there is a greater risk that the content being taught will not be understood by the learner. This knowledge of the human brain is critical for teachers because it helps them to design instructional strategies that optimise the load on students' working memories to help maximise learning. CLT supports the use of explicit instruction (especially for novice learners). Research shows that direct, explicit guidance is more effective and efficient for teaching new content and skills to novices.

How the Human Brain Learns



The Two Types of Cognitive Load

Reduce Extraneous Load and Optimise Intrinsic Load

CLT identifies two main types of cognitive load: intrinsic and extraneous. Intrinsic cognitive load relates to the inherent difficulty of the subject matter being learnt. We must optimise intrinsic load by responding to and adjusting the difficulty of the learning content. Extraneous cognitive load relates to *how* the subject matter is taught. Extraneous load is the 'bad' type of cognitive load, because it does not directly contribute to learning and therefore must be reduced.

Prior Knowledge

Activate What Students Already Know

Tailoring lessons to students' existing knowledge and skills is crucial for optimal learning. This method of instruction encourages students to construct new knowledge based on their previous experiences, leading to more meaningful and lasting learning. By adjusting the complexity of tasks based on students' knowledge and abilities, you can minimise cognitive load. Strategies that help students to activate prior knowledge (PK) and relate new information (NI) to what they already know are: analogies, real-world examples, and comparing and contrasting with familiar ideas.

Worked Examples

Guide Students Step By Step With New Skills

A 'worked example' is a problem that has already been solved for the student, with every step fully explained and clearly shown. Research consistently demonstrates that students who are given lots of worked examples learn new content more effectively than students who are required to solve the same problem themselves. Unguided problem-solving can overburden the WM and therefore impact the transfer of knowledge to the LTM. Worked examples are most effective when combined with the teacher thinking aloud because it enables them to externalise their thinking process when working through a problem.

Completion Tasks

Increase Independent Problem Solving

Fully guided instruction is effective for teaching new material, but as students become more skilled, it becomes counterproductive. Too much guidance can burden working memory. Independent problem-solving is more beneficial as students develop expertise. To do this effectively, monitor students' knowledge and skill levels, and adjust your teaching strategies accordingly as students gradually become more and more proficient. This might mean omitting some of the steps from a worked example (also known as completion tasks) or gradually giving the students fewer worked examples.

The 'Redundancy/Coherency Effect'

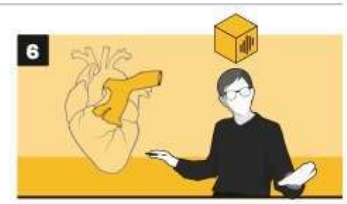
Cut out unnecessary or repeated information

To enhance learning and reduce any unnecessary cognitive load on students' working memory, it's crucial to eliminate non-essential information. This means keeping learning materials as simple as possible and not repeating the same points in different ways. In multimedia presentations (such as PowerPoint), consider breaking down new information across slides, verbalising text instead of displaying it, and omitting non-pertinent images. Be mindful that what is critical for beginners may become superfluous for more advanced learners, and adapt content to match their growing expertise.

The 'Split Attention Effect'

Present All Essential Information Together

Cognitive overload can occur when students have to split their attention between two or more sources of information that have been presented separately, but can only be understood in reference to each other (for example a scientific diagram). Evidence suggests that this separation has negative consequences and should be eliminated wherever possible. With this in mind, teachers should design learning materials that integrate labels, incorporate written instructions next to tasks and utilise visual cues to stress key information on worksheets and other learning resources.



The 'Modality Effect'

Present Information Verbally And Visually

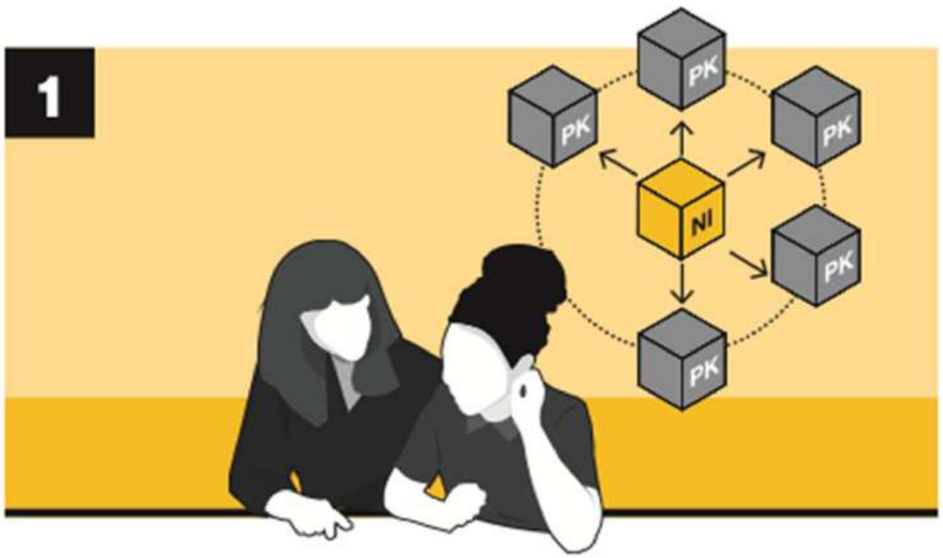
The 'modality effect' refers to the strategy of using both auditory and visual modes of communication to reduce cognitive load. According to dual coding theory, our WM has two channels. One for processing visual information and one for processing auditory information. The 'modality effect' leverages dual channels of working memory to increase its capacity. To do this, teachers can verbalise information instead of presenting it for students to both read *and* hear. For example, when presenting a diagram, use visual cues only (such as pointing) and then explain the labels using your voice.

La théorie de la charge cognitive en pratique

- Stratégie 1 : S’appuyer sur les connaissances antérieures
- Stratégie 2 : Les exemples résolus
- Stratégie 3 : Augmenter l’autonomie
- Stratégie 4 : Supprimer toute information inutile
- Stratégie 5 : Présenter les informations essentielles ensemble
- Stratégie 6 : Présenter des informations oralement et visuellement

Stratégie #1:

S'APPUYER SUR LES CONNAISSANCES ANTÉRIEURES DES ÉLÈVES



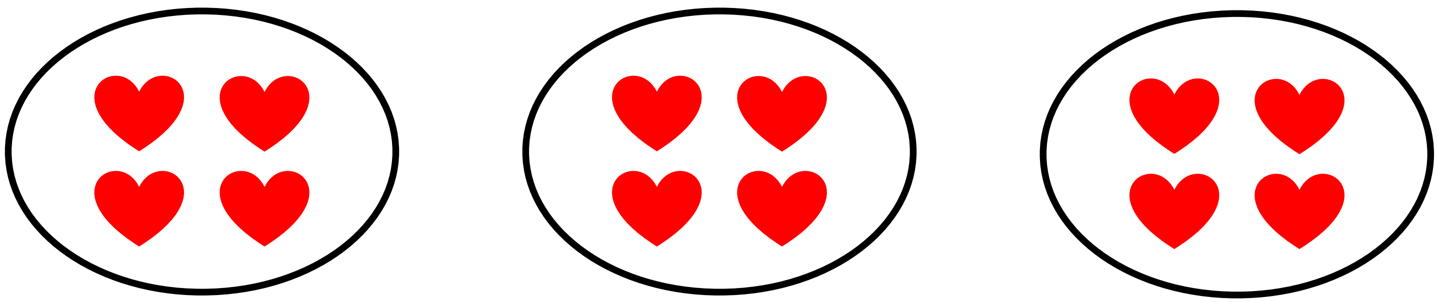
4 + 4 = 8

alors... 4 + 5 = 9

po pu la tion

population

Pouvez vous compter par bonds de 4?

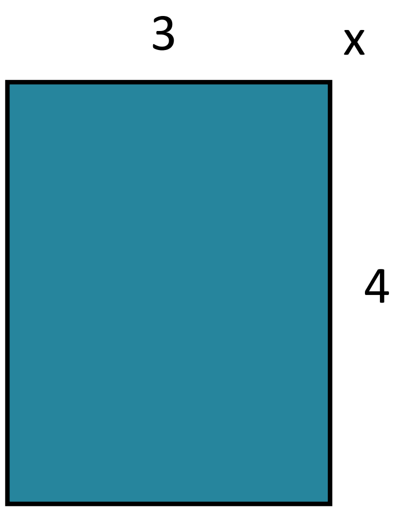


4 8 12

J'ai trois groupes de quatre. $3 \times 4 = 12$

La multiplication *est comme* … compter par bonds

Apprendre à calculer l'aire

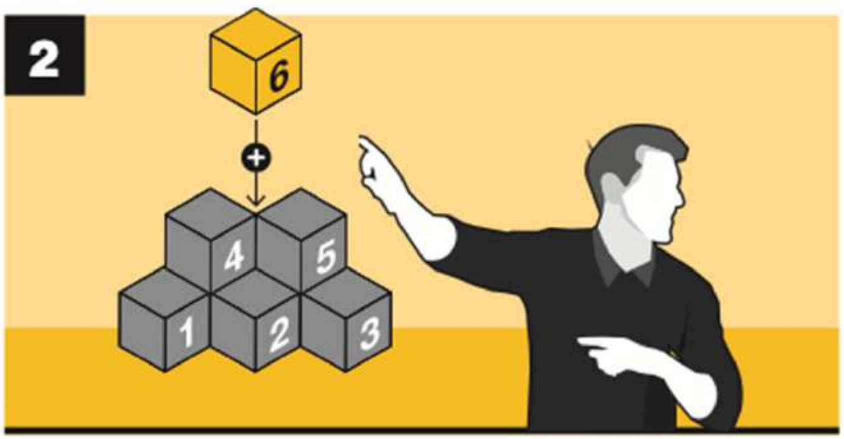


L'aire *est comme…*

une matrice!

Stratégie #2:

EXEMPLES RÉSOLUS POUR ENSEIGNER UN NOUVEAU CONTENU



$x + 3 = 15$

On veut trouver la valeur de x.
Comment isoler x?
Comment enlever le 3?

$-3 \quad -3$

$x + 3 = 15$

Si je soustrais 3 de chaque côté, mon équation, est-elle encore équilibrée?

$x = 12$

Je vois que x est égal à 12

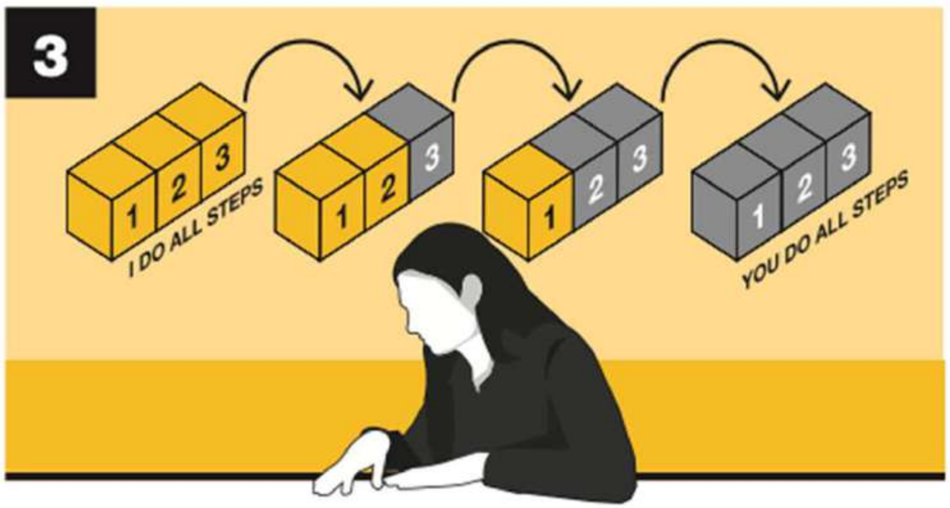
Problème #1

Pendant ses vacances d'été, M. Comeau a mangé **10** glaces à l'eau. Dans la boîte, il y avait des glaces à l'eau à la cerise et à la framboise bleue. Quelles sont toutes les combinaisons de saveurs de glaces à l'eau possibles qu'il aurait pu manger?

Cerise	Framboise bleue
0	10
1	9
2	8
3	7
4	6
5	5
6	4
7	3
8	2
9	1
10	0

Stratégie #3:

AUGMENTER L'AUTONOMIE



- Je fais
- Nous faisons
- **Tu fais**

Problème #2

Pendant ses vacances d'été, M. Comeau a mangé **10** glaces à l'eau. S'il a mangé au moins 2 glaces à l'eau de chaque type, quelles sont toutes les combinaisons de saveurs de glaces à l'eau possibles qu'il aurait pu manger?

Cerise	Framboise bleue
2	8
3	7
4	6
5	5
6	4
7	3
8	2

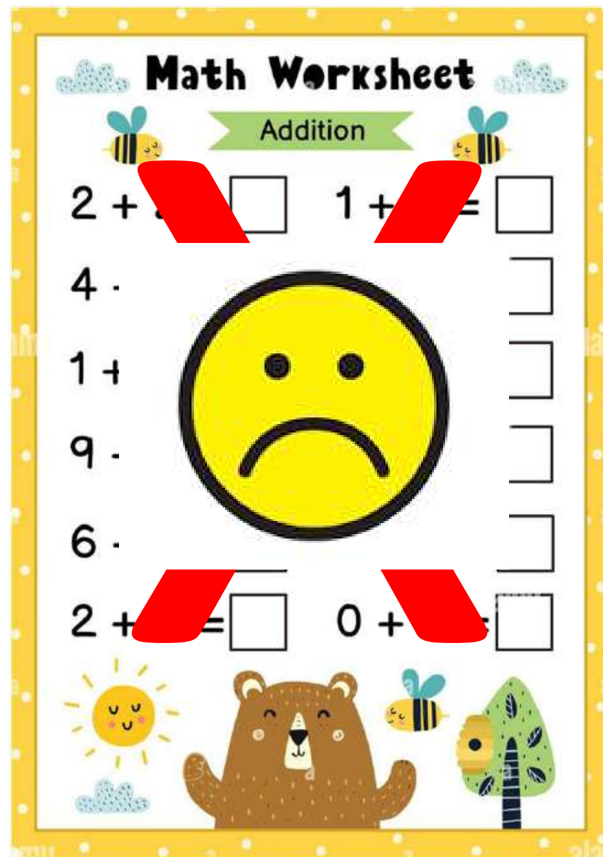
Problème #10

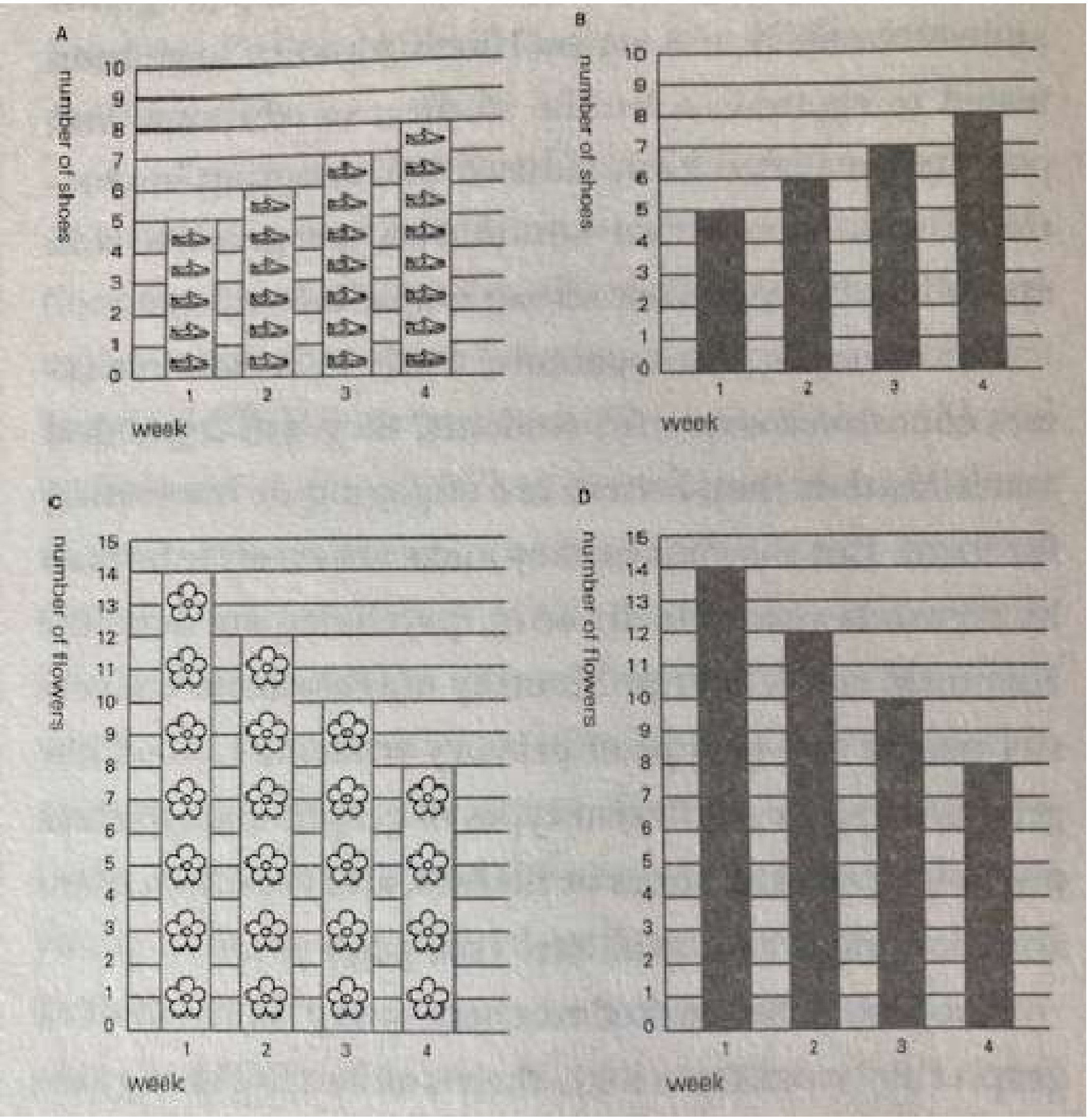
J’ai des pièces de 5 cents et des pièces de 10 cents. Quelles sont toutes les combinaisons possibles pour faire 0,50$?

Valeur des 0,05$	Montant de 0,05$	Montant de 0,10$	Valeur des 0,10$
0,50$	10	0	0,00$
0,40$	8	1	0,10$
0,30$	6	2	0,20$
0,20$	4	3	0,30$
0,10$	2	4	0,40$
0,00$	0	5	0,50$

Stratégie #4:

SUPPRIMER TOUTE INFORMATION INUTILE





SUPPRIMER TOUTE INFORMATION INUTILE

Kaminski & Sloutsky (2013) ont trouvé que les élèves ont mieux appris à lire les graphiques à bandes A, C ou B, D?

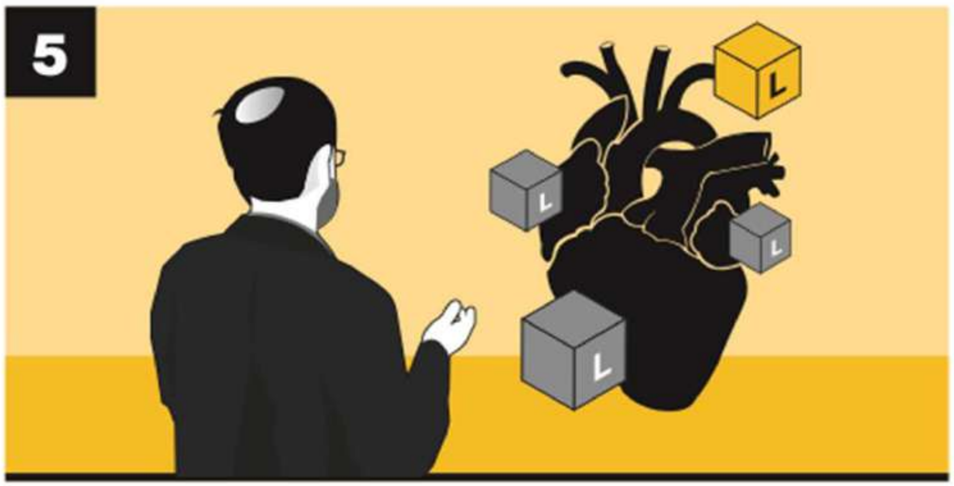
Quels ont été les malentendus potentiels ?

Au lieu d'apprendre à lire l'échelle du graphique, les élèves ont compté le nombre d'objets.

Mighton, J. (2020). *All Things Being Equal.*

Stratégie # 5

PRÉSENTER LES INFORMATIONS ESSENTIELLES ENSEMBLE



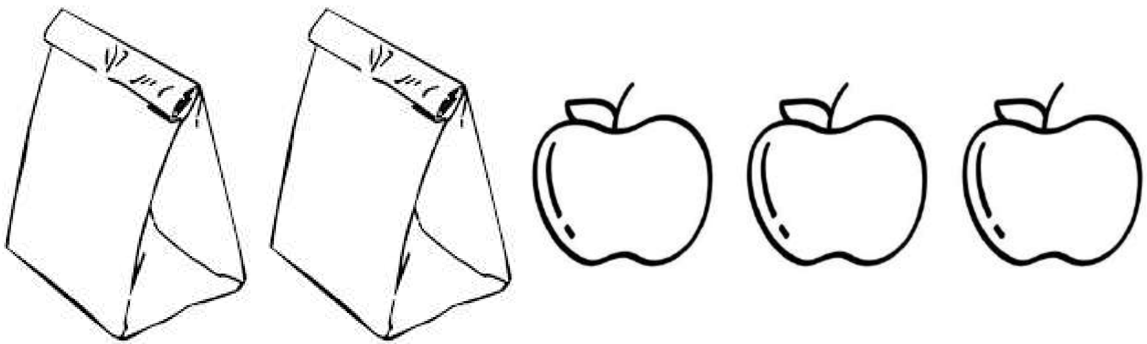
4 + 4 = 8

alors… 4 + 5 = 9

10 + 7 = 17

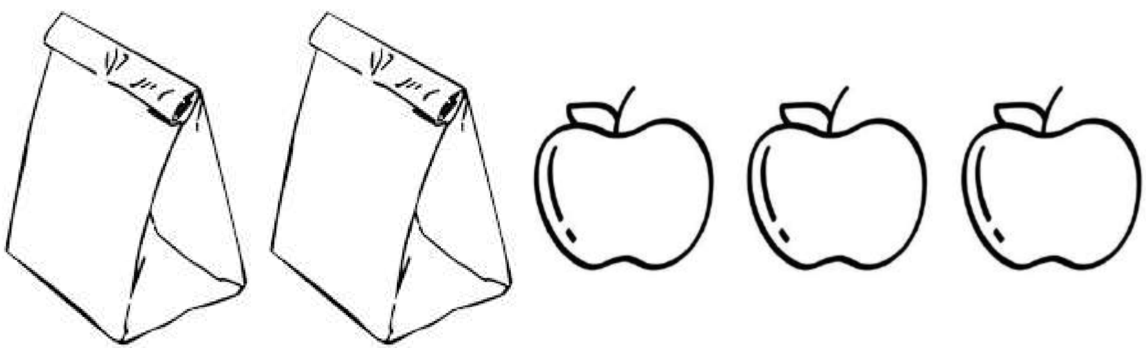
alors… 9 + 7 = 16

10 + 7 = 17 alors… 9 + 7 = 16



2b + 3

Expression

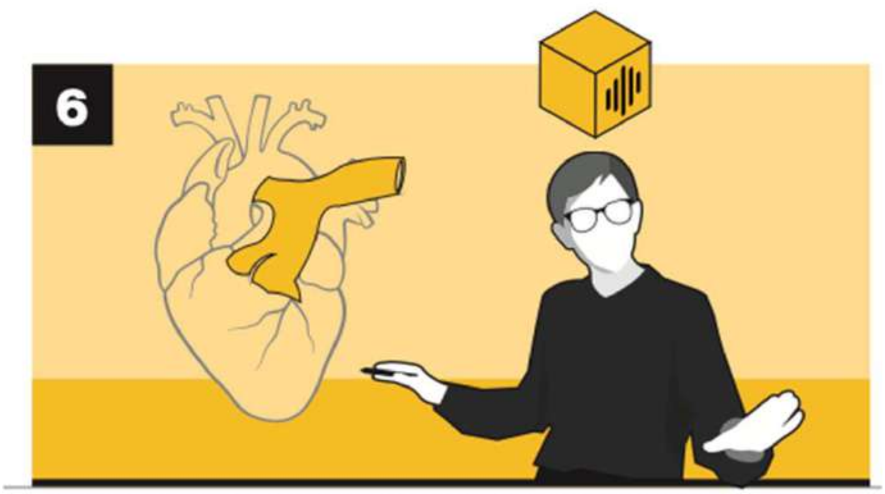


2b + 3 = 13

Équation

Stratégie # 6

PRÉSENTER DES INFORMATIONS ORALEMENT ET VISUELLEMENT



Notre cerveau possède **deux canaux principaux** de traitement de l'information :

- **Visuel-spatial**
- **Auditif-verbal**

L’objet d’apprentissage ciblé … +9

S1: Connaissances antérieures

S2: Exemples résolus

S3: Augmenter l’autonomie

S4 : Supprimer info inutile

S5: Infos essentielles ensembles

S6: Oral et visuel

2 + 10 = ____

3 + 10 = ____

4 + 10 = ____

2 + 10 = ____
2 + 9 = ____

3 + 10 = ____
3 + 9 = ____

4 + 10 = ____
4 + 9 = ____

2 + 9 = ____

3 + 9 = ____

4 + 9 = ____

Comprendre la formule de l'aire d'un triangle

S1: Connaissances antérieures

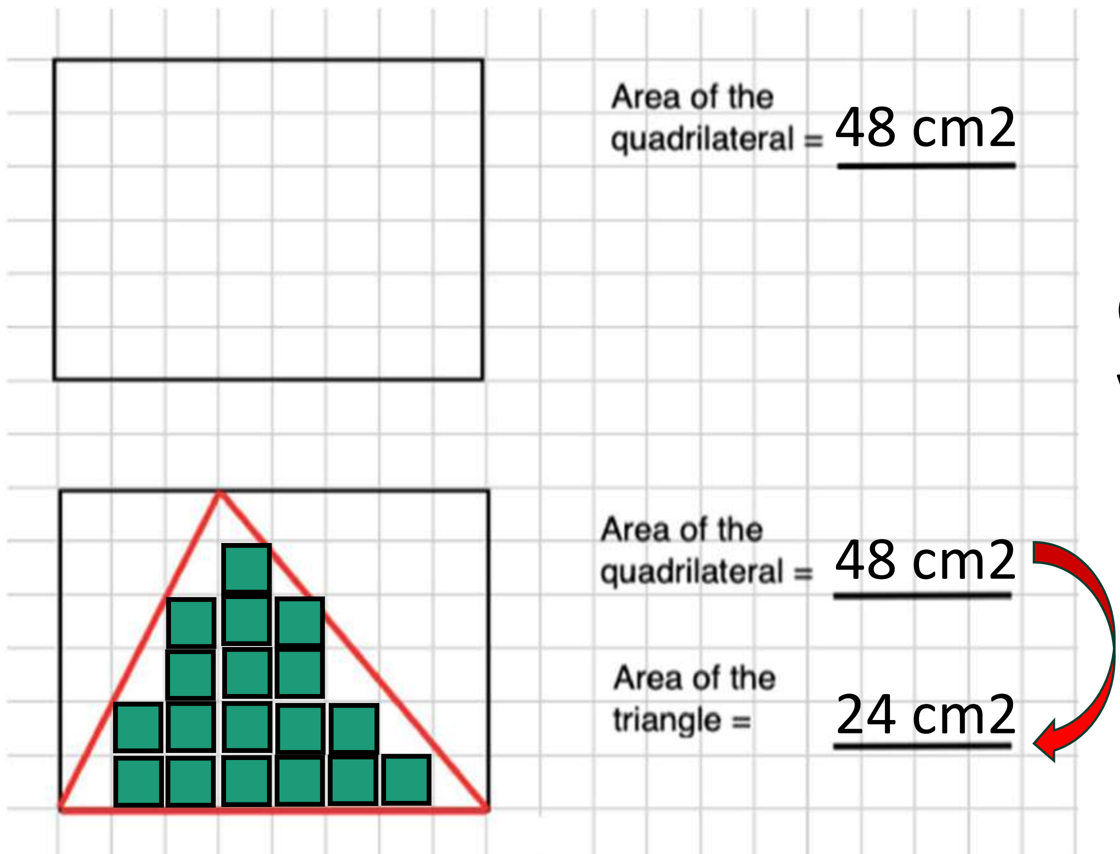
S2: Exemples résolus

S3: Augmenter l'autonomie

S4 : Supprimer info inutile

S5: Infos essentielles ensembles

S6: Oral et visuel



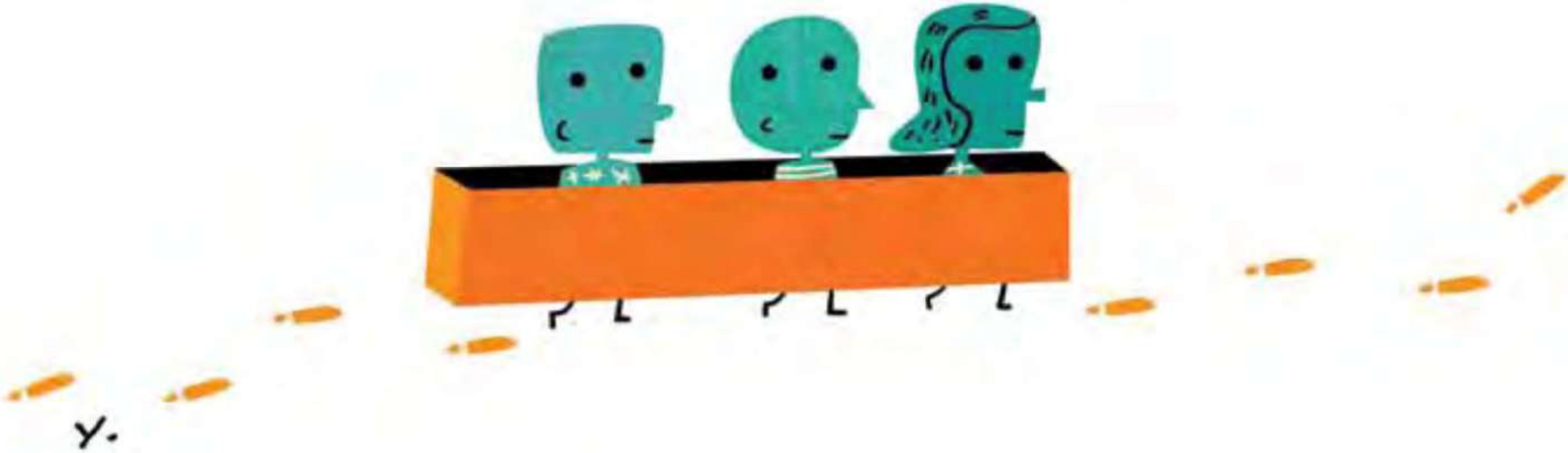
Qu'est-ce que vous remarquez?

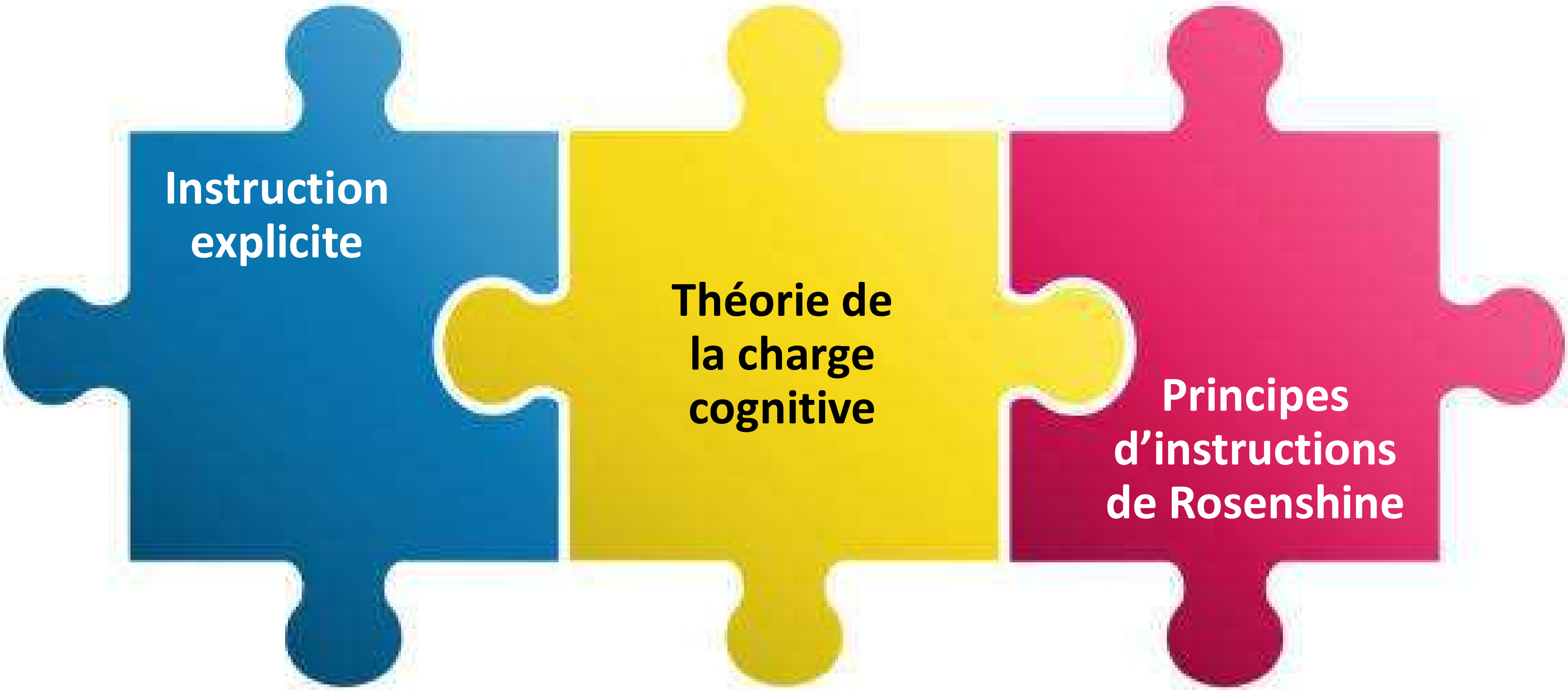
A □ = L x W

A △ = $\frac{L \times W}{2}$

Principles of Instruction

Research-Based Strategies That All Teachers Should Know




Instruction explicite
Théorie de la charge cognitive
Principes d’instructions de Rosenshine

Principes d’instruction

1. Commencer une leçon par une brève révision des leçons précédentes.
2. Présenter le nouveau matériel par petites étapes avec suffisamment de pratique après chaque étape.
3. Fournir des modèles.
4. Poser un grand nombre de questions et vérifier les réponses de tous les élèves.
5. Guider la pratique de l'élève.
6. Vérifier la compréhension de l'élève.
7. Exiger et contrôler la pratique indépendante.
8. Fournir des échafaudages pour les tâches difficiles.
9. Obtenir un taux de réussite élevé.
10. Impliquer les élèves dans les révisions hebdomadaires et mensuelles.

1. Commencer une leçon par une brève révision des leçons précédentes.

17 x 5 =	23 x 7 =
10 x 5 = 50	20 x 7 = 140
7 x 5 = 35	3 x 7 = 21
= 85	= 161

2. Présenter le nouveau matériel par petites étapes avec suffisamment de pratique après chaque étape.

3. Fournir des modèles (exemples résolus)

```
 17
x 5
---
```

```
 10       7
x 5     x 5
---     ---
 50      35

   = 85
```

```
 17          +3
x 5          17
---         x 5
 35         ---
+50           5
---         +80
 85         ---
             85
```

4. Poser un grand nombre de questions et vérifier les réponses de tous les élèves.
5. Guider la pratique de l'élève.
6. Vérifier la compréhension de l'élève.

13	18	14
x 6	x 4	x 7

7. Exiger et contrôler la pratique indépendante.

$$\begin{array}{r} 43 \\ \times \quad 8 \\ \hline \end{array} \qquad \begin{array}{r} 47 \\ \times \quad 3 \\ \hline \end{array} \qquad \begin{array}{r} 16 \\ \times \quad 8 \\ \hline \end{array} \qquad \begin{array}{r} 71 \\ \times \quad 7 \\ \hline \end{array} \qquad \begin{array}{r} 19 \\ \times \quad 8 \\ \hline \end{array}$$

344 - 141 - 128 - 497 - 152

8. Fournir des échafaudages pour les tâches difficiles.

Problème #1

Pendant ses vacances d'été, M. Comeau a mangé **10** glaces à l'eau. Dans la boîte, il y avait des glaces à l'eau à la cerise et à la framboise bleue. Quelles sont toutes les combinaisons de saveurs de glaces à l'eau possibles qu'il aurait pu manger?

Cerise	Framboise bleue
0	10
1	9
2	8
3	7
4	6
5	5
6	4
7	3
8	2
9	1
10	0

→

Problème #10

J'ai des pièces de 5 cents et des pièces de 10 cents. Quelles sont toutes les combinaisons possibles pour faire 0,50$?

Valeur des 0,05$	Montant de 0,05$	Montant de 0,10$	Valeur des 0,10$
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0,40$	8	1	0,10$
0,30$	6	2	0,20$
0,20$	4	3	0,30$
0,10$	2	4	0,40$
0,00$	0	5	0,50$

9. Obtenir un taux de réussite élevé.

ARTICLE

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The Eighty Five Percent Rule for optimal learning

Robert C. Wilson[1,2*], Amitai Shenhav[3,4], Mark Straccia[5] & Jonathan D. Cohen[6]

10. Impliquer les élèves dans les révisions hebdomadaires et mensuelles.

Répétition - Répéter de nouvelles informations oralement, mentalement ou par écrit.

Pratique de récupération/Retrieval practice - cartes mémoire, couvrir/copier/comparer, écrire des algorithmes mémorisés.

Pratique distribuée/Distributed practice - Pratique de récupération sur plusieurs jours.

Surapprentissage avec espacement/overlearning – spaced practice - répété pendant plusieurs jours, semaines et mois par la suite.

***Designing mathematics standards in agreement with science* -** Hartman, Hart, Nelson, Kirschner

Science of Math/Learning Websites/Articles

https://evidencebased.education/ - Australia
https://www.thescienceofmath.com/ - Amanda VanderHeyden +

Cognitive Load Theory – John Sweller
Principles of Instruction – Barak Rosenshine
Explicit Instruction - Anita Archer
Chalk & Talk – Anna Stokke
Sarah Powell, Paul Kirschner

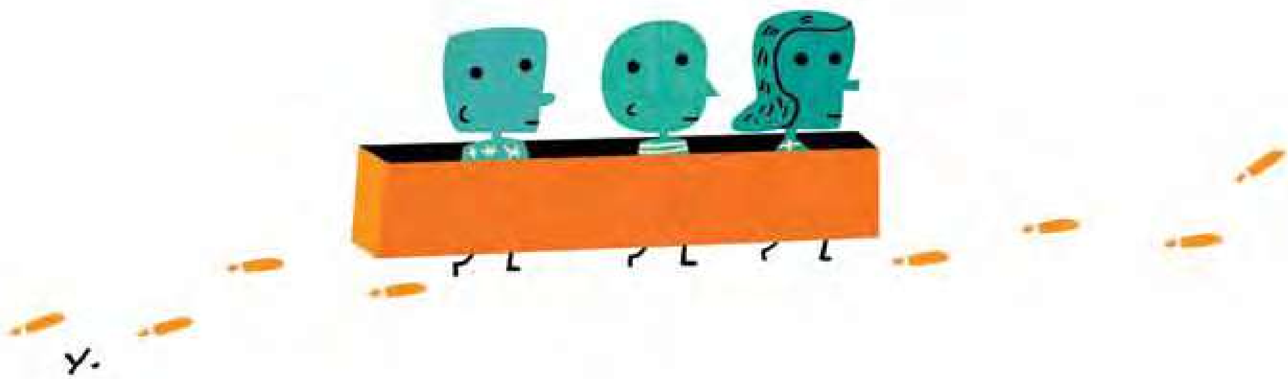
Facebook groups – The Science of Math
LinkedIn

FIN!

Carla French - cbfrench@cbe.ab.ca

Principles of Instruction

Research-Based Strategies That All Teachers Should Know



By Barak Rosenshine

This article presents 10 research-based principles of instruction, along with suggestions for classroom practice. These principles come from three sources: (a) research in cognitive science, (b) research on master teachers, and (c) research on cognitive supports. Each is briefly explained below.

A: Research in cognitive science: This research focuses on how our brains acquire and use information. This cognitive research also provides suggestions on how we might overcome the limitations of our working memory (i.e., the mental "space" in which thinking occurs) when learning new material.

B: Research on the classroom practices of master teachers: Master teachers are those teachers whose classrooms made the highest gains on achievement tests. In a series of studies, a wide range of teachers were observed as they taught, and the investigators coded how they presented new material, how and whether they checked for student understanding, the types of support they provided to their students, and a number of other instructional activities. By also gathering student achievement data, researchers were able to identify the ways in which the more and less effective teachers differed.

C: Research on cognitive supports to help students learn complex tasks: Effective instructional procedures—such as thinking aloud, providing students with scaffolds, and providing students with models—come from this research.

Barak Rosenshine is an emeritus professor of educational psychology in the College of Education at the University of Illinois at Urbana-Champaign. A distinguished researcher, he has spent much of the past four decades identifying the hallmarks of effective teaching. He began his career as a high school history teacher in the Chicago public schools. This article is adapted with permission from Principles of Instruction *by Barak Rosenshine. Published by the International Academy of Education in 2010, the original report is available at www.ibe.unesco.org/fileadmin/user_upload/Publications/Educational_Practices/EdPractices_21.pdf.*

ILLUSTRATIONS BY JAMES YANG

Even though these are three very different bodies of research, there is *no conflict at all* between the instructional suggestions that come from each of these three sources. In other words, these three sources supplement and complement each other. The fact that the instructional ideas from three different sources supplement and complement each other gives us faith in the validity of these findings.

Education involves helping a novice develop strong, readily accessible background knowledge. It's important that background knowledge be readily accessible, and this occurs when knowledge is well rehearsed and tied to other knowledge. The most effective teachers ensured that their students efficiently acquired, rehearsed, and connected background knowledge by providing a good deal of instructional support. They provided this support by teaching new material in manageable amounts, modeling, guiding student practice, helping students when they made errors, and providing for sufficient practice and review. Many of these teachers also went on to experiential, hands-on activities, but they always did the experiential activities *after*, not before, the basic material was learned.

The following is a list of some of the instructional principles that have come from these three sources. These ideas will be described and discussed in this article:

- Begin a lesson with a short review of previous learning.[1]
- Present new material in small steps with student practice after each step.[2]
- Ask a large number of questions and check the responses of all students.[3]
- Provide models.[4]
- Guide student practice.[5]
- Check for student understanding.[6]
- Obtain a high success rate.[7]
- Provide scaffolds for difficult tasks.[8]
- Require and monitor independent practice.[9]
- Engage students in weekly and monthly review.[10]

ensured that the students had a firm grasp of the skills and concepts that would be needed for the day's lesson.

Effective teachers also reviewed the knowledge and concepts that were relevant for that day's lesson. It is important for a teacher to help students recall the concepts and vocabulary that will be relevant for the day's lesson because our working memory is very limited. If we do not review previous learning, then we will have to make a special effort to recall old material while learning new material, and this makes it difficult for us to learn the new material.

Daily review is particularly important for teaching material that will be used in subsequent learning. Examples include reading sight words (i.e., any word that is known by a reader automatically), grammar, math facts, math computation, math factoring, and chemical equations.

When planning for review, teachers might want to consider which words, math facts, procedures, and concepts need to become automatic, and which words, vocabulary, or ideas need to be reviewed before the lesson begins.

In addition, teachers might consider doing the following during their daily review:

- Correct homework.
- Review the concepts and skills that were practiced as part of the homework.
- Ask students about points where they had difficulties or made errors.
- Review material where errors were made.
- Review material that needs overlearning (i.e., newly acquired skills should be practiced well beyond the point of initial mastery, leading to automaticity).

The most effective teachers ensured that students efficiently acquired, rehearsed, and connected knowledge. Many went on to hands-on activities, but always *after*, not before, the basic material was learned.

1. Begin a lesson with a short review of previous learning: Daily review can strengthen previous learning and can lead to fluent recall.

Research findings

Daily review is an important component of instruction. Review can help us strengthen the connections among the material we have learned. The review of previous learning can help us recall words, concepts, and procedures effortlessly and automatically when we need this material to solve problems or to understand new material. The development of expertise requires thousands of hours of practice, and daily review is one component of this practice.

For example, daily review was part of a successful experiment in elementary school mathematics. Teachers in the experiment were taught to spend eight minutes every day on review. Teachers used this time to check the homework, go over problems where there were errors, and practice the concepts and skills that needed to become automatic. As a result, students in these classrooms had higher achievement scores than did students in other classrooms.

Daily practice of vocabulary can lead to seeing each practiced word as a unit (i.e., seeing the whole word automatically rather than as individual letters that have to be sounded out and blended). When students see words as units, they have more space available in their working memory, and this space can now be used for comprehension. Mathematical problem solving is also improved when the basic skills (addition, multiplication, etc.) are overlearned and become automatic, thus freeing working-memory capacity.

In the classroom

The most effective teachers in the studies of classroom instruction understood the importance of practice, and they began their lessons with a five- to eight-minute review of previously covered material. Some teachers reviewed vocabulary, formulae, events, or previously learned concepts. These teachers provided additional practice on facts and skills that were needed for recall to become automatic.

Effective teacher activities also included reviewing the concepts and skills that were necessary to do the homework, having students correct each others' papers, and asking about points on which the students had difficulty or made errors. These reviews

2. Present new material in small steps with student practice after each step: Only present small amounts of new material at any time, and then assist students as they practice this material.

Research findings

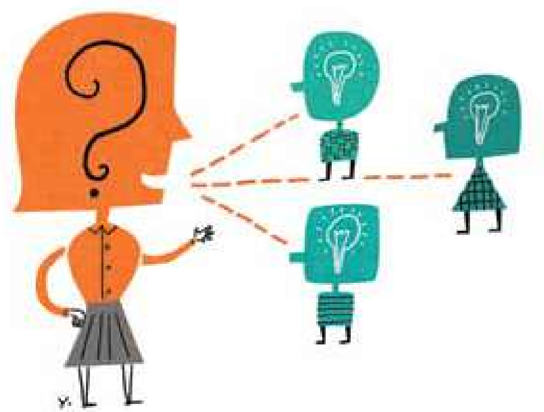
Our working memory, the place where we process information, is small. It can only handle a few bits of information at once—too much information swamps our working memory. Presenting too much material at once may confuse students because their working memory will be unable to process it.

Therefore, the more effective teachers do not overwhelm their students by presenting too much new material at once. Rather, these teachers only present small amounts of new material at any time, and then assist the students as they practice this material. Only after the students have mastered the first step do teachers proceed to the next step.

The procedure of first teaching in small steps and then guiding student practice represents an appropriate way of dealing with the limitation of our working memory.

In the classroom

The more successful teachers did not overwhelm their students by presenting too much new material at once. Rather, they presented only small amounts of new material at one time, and they taught in such a way that each point was mastered before the next point was introduced. They checked their students' understanding on each point and retaught material when necessary.



Some successful teachers taught by giving a series of short presentations using many examples. The examples provided concrete learning and elaboration that were useful for processing new material.

Teaching in small steps requires time, and the more effective teachers spent more time presenting new material and guiding student practice than did the less effective teachers. In a study of mathematics instruction, for instance, the most effective mathematics teachers spent about 23 minutes of a 40-minute period in lecture, demonstration, questioning, and working examples. In contrast, the least effective teachers spent only 11 minutes presenting new material. The more effective teachers used this extra time to provide additional explanations, give many examples, check for student understanding, and provide sufficient instruction so that the students could learn to work independently without difficulty. In one study, the least effective teachers asked only nine questions in a 40-minute period. Compared with the successful teachers, the less effective teachers gave much shorter presentations and explanations, and then passed out worksheets and told students to solve the problems. The less successful teachers were then observed going from student to student and having to explain the material again.

Similarly, when students were taught a strategy for summarizing a paragraph, an effective teacher taught the strategy using small steps. First, the teacher modeled and thought aloud as she identified the topic of a paragraph. Then, she led practice on identifying the topics of new paragraphs. Then, she taught students to identify the main idea of a paragraph. The teacher modeled this step and then supervised the students as they practiced both finding the topic and locating the main idea. Following this, the teacher taught the students to identify the supporting details in a paragraph. The teacher modeled and thought aloud, and then the students practiced. Finally, the students practiced carrying out all three steps of this strategy. Thus, the strategy of summarizing a paragraph was divided into smaller steps, and there was modeling and practice at each step.

3. Ask a large number of questions and check the responses of all students: Questions help students practice new information and connect new material to their prior learning.

Research findings

Students need to practice new material. The teacher's questions and student discussion are a major way of providing this necessary practice. The most successful teachers in these studies spent more than half of the class time lecturing, demonstrating, and asking questions.

Questions allow a teacher to determine how well the material has been learned and whether there is a need for additional instruction. The most effective teachers also ask students to explain the process they used to answer the question, to explain how the answer was found. Less successful teachers ask fewer questions and almost no process questions.

In the classroom

In one classroom-based experimental study, one group of teachers was taught to follow the presentation of new material with lots of questions.[11] They were taught to increase the number of factual questions and process questions they asked during this guided practice. Test results showed that their students achieved higher scores than did students whose teachers did not receive the training.

Imaginative teachers have found ways to involve all students in answering questions. Examples include having all students:

- Tell the answer to a neighbor.
- Summarize the main idea in one or two sentences, writing the summary on a piece of paper and sharing this with a neighbor, or repeating the procedures to a neighbor.
- Write the answer on a card and then hold it up.
- Raise their hands if they know the answer (thereby allowing the teacher to check the entire class).
- Raise their hands if they agree with the answer that someone else has given.

Across the classrooms that researchers observed, the purpose of all these procedures was to provide active participation for the students and also to allow the teacher to see how many students were correct and confident. The teacher may then reteach some material when it was considered necessary. An alternative was for students to write their answers and then trade papers with each other.

Other teachers used choral responses to provide sufficient practice when teaching new vocabulary or lists of items. This made the practice seem more like a game. To be effective, however, all students needed to start together, on a signal. When students did not start together, only the faster students answered.

In addition to asking questions, the more effective teachers facilitated their students' rehearsal by providing explanations, giving more examples, and supervising students as they practiced the new material.

The following is a series of stems[12] for questions that teachers might ask when teaching literature, social science content, or science content to their students. Sometimes, students may also develop questions from these stems to ask questions of each other.

How are __________ and __________ alike?
What is the main idea of __________?
What are the strengths and weaknesses of __________?
In what way is __________ related to __________?
Compare __________ and __________ with regard to __________.
What do you think causes __________?
How does __________ tie in with what we have learned before?
Which one is the best __________, and why?
What are some possible solutions for the problem of __________?
Do you agree or disagree with this statement: __________?
What do you still not understand about __________?

4. Provide models: Providing students with models and worked examples can help them learn to solve problems faster.

Research findings

Students need cognitive support to help them learn to solve problems. The teacher modeling and thinking aloud while demonstrating how to solve a problem are examples of effective cognitive support. Worked examples (such as a math problem for which the teacher not only has provided the solution but has clearly laid out each step) are another form of modeling that has been developed by researchers. Worked examples allow students to focus on the specific steps to solve problems and thus reduce the cognitive load on their working memory. Modeling and worked examples have been used successfully in mathematics, science, writing, and reading comprehension.

In the classroom

Many of the skills that are taught in classrooms can be conveyed by providing prompts, modeling use of the prompt, and then guiding students as they develop independence. When teaching reading comprehension strategies, for example, effective teachers provided students with prompts that the students could use to ask themselves questions about a short passage. In one class, students were given words such as "who," "where," "why," and "how" to help them begin a question. Then, everyone read a passage and the teacher modeled how to use these words to ask questions. Many examples were given.

Next, during guided practice, the teacher helped the students practice asking questions by helping them select a prompt and

Many of the skills taught in classrooms can be conveyed by providing prompts, modeling use of the prompt, and then guiding students as they develop independence.

develop a question that began with that prompt. The students practiced this step many times with lots of support from the teacher.

Then, the students read new passages and practiced asking questions on their own, with support from the teacher when needed. Finally, students were given short passages followed by questions, and the teacher expressed an opinion about the quality of the students' questions.

This same procedure—providing a prompt, modeling, guiding practice, and supervising independent practice—can be used for many tasks. When teaching students to write an essay, for example, an effective teacher first modeled how to write each paragraph, then the students and teacher worked together on two or more new essays, and finally students worked on their own with supervision from the teacher.

Worked examples are another form of modeling that has been used to help students learn how to solve problems in mathematics and science. A worked example is a step-by-step demonstration of how to perform a task or how to solve a problem. The presentation of worked examples begins with the teacher modeling and explaining the steps that can be taken to solve a specific problem. The teacher also identifies and explains the underlying principles for these steps.

Usually, students are then given a series of problems to complete at their desks as independent practice. But, in research carried out in Australia, students were given a mixture of problems to solve and worked examples. So, during independent practice, students first studied a worked example, then they solved a problem; then they studied another worked example and solved another problem. In this way, the worked examples showed students how to focus on the essential parts of the problems. Of course, not all students studied the worked examples. To correct this problem, the Australian researchers also presented partially completed problems in which students had to complete the missing steps and thus pay more attention to the worked example.

5. Guide student practice: Successful teachers spend more time guiding students' practice of new material.

Research findings

It is not enough simply to present students with new material, because the material will be forgotten unless there is sufficient rehearsal. An important finding from information-processing research is that students need to spend additional time rephrasing, elaborating, and summarizing new material in order to store this material in their long-term memory. When there has been sufficient rehearsal, the students are able to retrieve this material easily and thus are able to make use of this material to foster new learning and aid in problem solving. But when the rehearsal time is too short, students are less able to store, remember, or use the material. As we know, it is relatively easy to place something in a filing cabinet, but it can be very difficult to recall where exactly we filed it. Rehearsal helps us remember where we filed it so we can access it with ease when needed.

A teacher can facilitate this rehearsal process by asking questions; good questions require students to process and rehearse the material. Rehearsal is also enhanced when students are asked to summarize the main points, and when they are supervised as they practice new steps in a skill. The quality of storage in long-term memory will be weak if students only skim the material and do not engage in it. It is also important that all students process the new material and receive feedback, so they do not inadvertently store partial information or a misconception in long-term memory.

In the classroom

In one study, the more successful teachers of mathematics spent more time presenting new material and guiding practice. The more successful teachers used this extra time to provide additional explanations, give many examples, check for student understanding, and provide sufficient instruction so that the students could learn to work independently without difficulty. In contrast, the less successful teachers gave much shorter presentations and explanations, and then they passed out worksheets and told students to work on the problems. Under these conditions, the students made too many errors and had to be retaught the lesson.

The most successful teachers presented only small amounts of material at a time. After this short presentation, these teachers then guided student practice. This guidance often consisted of the teacher working the first problems at the blackboard and explaining the reason for each step, which served as a model for the students. The guidance also included asking students to come to the blackboard to work out problems and discuss their procedures. Through this process, the students seated in the classroom saw additional models.

Although most teachers provided some guided practice, the most successful teachers spent more time in guided practice, more time asking questions, more time checking for understanding, more time correcting errors, and more time having students work out problems with teacher guidance.

Teachers who spent more time in guided practice and had higher success rates also had students who were more engaged during individual work at their desks. This finding suggests that, when teachers provided sufficient instruction during guided practice, the students were better prepared for the independent practice (e.g., seatwork and homework activities), but when the guided practice was too short, the students were not prepared for the seatwork and made more errors during independent practice.

6. Check for student understanding: Checking for student understanding at each point can help students learn the material with fewer errors.

Research findings

The more effective teachers frequently checked to see if all the students were learning the new material. These checks provided some of the processing needed to move new learning into long-term memory. These checks also let teachers know if students were developing misconceptions.

In the classroom

Effective teachers also stopped to check for student understanding. They checked for understanding by asking questions, by asking students to summarize the presentation up to that point or to repeat directions or procedures, or by asking students whether they agreed or disagreed with other students' answers. This checking has two purposes: (a) answering the questions might cause the students to elaborate on the material they have learned and augment connections to other learning in their long-term memory, and (b) alerting the teacher to when parts of the material need to be retaught.

In contrast, the less effective teachers simply asked, "Are there any questions?" and, if there were no questions, they assumed the students had learned the material and proceeded to pass out worksheets for students to complete on their own.

Another way to check for understanding is to ask students to think aloud as they work to solve mathematical problems, plan an essay, or identify the main idea in a paragraph. Yet another check is to ask students to explain or defend their position to others. Having to explain a position may help students integrate and elaborate their knowledge in new ways, or may help identify gaps in their understanding.

Another reason for the importance of teaching in small steps, guiding practice, and checking for understanding (as well as obtaining a high success rate, which we'll explore in principle 7) comes from the fact that we all construct and reconstruct knowledge as we learn and use what we have learned. We cannot simply repeat what we hear word for word. Rather, we connect our understanding of the new information to our existing concepts or "schema," and we then construct a mental summary (i.e., the gist of what we have heard). However, when left on their own, many students make errors in the process of constructing this mental summary. These errors occur, particularly, when the information is new and the student does not have adequate or well-formed background knowledge. These constructions are not errors so much as attempts by the students to be logical in an area where their background knowledge is weak. These errors are so common that there is a research literature on the development and correction of student misconceptions in science. Providing guided practice after teaching small amounts of new material, and checking for student understanding, can help limit the development of misconceptions.

The most successful teachers spent more time in guided practice, more time asking questions, more time checking for understanding, and more time correcting errors.

7. Obtain a high success rate: It is important for students to achieve a high success rate during classroom instruction.

Research findings

In two of the major studies on the impact of teachers, the investigators found that students in classrooms with more effective teachers had a higher success rate, as judged by the quality of their oral responses during guided practice and their individual work. In a study of fourth-grade mathematics, it was found that 82 percent of students' answers were correct in the classrooms of the most successful teachers, but the least successful teachers had a success rate of only 73 percent. A high success rate during guided practice also leads to a higher success rate when students are working on problems on their own.

The research also suggests that the optimal success rate for fostering student achievement appears to be about 80 percent. A success rate of 80 percent shows that students are learning the material, and it also shows that the students are challenged.

In the classroom

The most effective teachers obtained this success level by teaching in small steps (i.e., by combining short presentations with supervised student practice), and by giving sufficient practice on each part before proceeding to the next step. These teachers frequently checked for understanding and required responses from all students.

It is important that students achieve a high success rate during instruction and on their practice activities. Practice, we are told, makes perfect, but practice can be a disaster if students are practicing errors! If the practice does not have a high success level, there is a chance that students are practicing and learning errors. Once errors have been learned, they are very difficult to overcome.

As discussed in the previous section, when we learn new material, we construct a gist of this material in our long-term memory. However, many students make errors in the process of constructing this mental summary. These errors can occur when the information is new and the student did not have adequate or well-formed background knowledge. These constructions are not errors so much as attempts by the students to be logical in an area where their background knowledge is weak. But students are more likely to develop misconceptions if too much material is presented at once, and if teachers do not check for student understanding. Providing guided practice after teaching small amounts of new material, and checking for student understanding, can help limit the development of misconceptions.

I once observed a class where an effective teacher was going from desk to desk during independent practice and suddenly realized that the students were having difficulty. She stopped the work, told the students not to do the problems for homework, and said she would reteach this material the next day. She stopped the work because she did not want the students to practice errors.

Unless all students have mastered the first set of lessons, there is a danger that the slower students will fall further behind when the next set of lessons is taught. So there is a need for a high success rate for *all* students. "Mastery learning" is a form of instruction where lessons are organized into short units and all students are required to master one set of lessons before they proceed to the next set. In mastery learning, tutoring by other students or by teachers is provided to help students master each unit. Variations of this approach, particularly the tutoring, might be useful in many classroom settings.

8. Provide scaffolds for difficult tasks: The teacher provides students with temporary supports and scaffolds to assist them when they learn difficult tasks.

Research findings

Investigators have successfully provided students with scaffolds, or instructional supports, to help them learn difficult tasks. A scaffold is a temporary support that is used to assist a learner. These scaffolds are gradually withdrawn as learners become more competent, although students may continue to rely on scaffolds when they encounter particularly difficult problems. Providing scaffolds is a form of guided practice.

Scaffolds include modeling the steps by the teacher, or thinking aloud by the teacher as he or she solves the problem. Scaffolds also may be tools, such as cue cards or checklists, that complete part of the task for the students, or a model of the completed task against which students can compare their own work.

One characteristic of effective teachers is their ability to anticipate students' errors and warn them about possible errors some of them are likely to make.

The process of helping students solve difficult problems by modeling and providing scaffolds has been called "cognitive apprenticeship." Students learn strategies and content during this apprenticeship that enable them to become competent readers, writers, and problem solvers. They are aided by a master who models, coaches, provides supports, and scaffolds them as they become independent.

In the classroom

One form of scaffolding is to give students prompts for steps they might use. Prompts such as "who," "why," and "how" have helped students learn to ask questions while they read. Teaching students to ask questions has been shown to help students' reading comprehension.

Similarly, one researcher developed the following prompt to help students organize material.[13]

1. Draw a central box and write the title of the article in it.
2. Skim the article to find four to six main ideas.
3. Write each main idea in a box below the central box.
4. Find and write two to four important details to list under each main idea.

Another form of scaffolding is thinking aloud by the teacher. For example, teachers might think aloud as they try to summarize a paragraph. They would show the thought processes they go through as they determine the topic of the paragraph and then use the topic to generate a summary sentence. Teachers might think aloud while solving a scientific equation or writing an essay, and at the same time provide labels for their mental processes. Such thinking aloud provides novice learners with a way to observe "expert thinking" that is usually hidden from the student. Teachers also can study their students' thought processes by asking them to think aloud during problem solving.

One characteristic of effective teachers is their ability to anticipate students' errors and warn them about possible errors some of them are likely to make. For example, a teacher might have students read a passage and then give them a poorly written topic sentence to correct. In teaching division or subtraction, the teacher may show and discuss with students the mistakes other students have frequently made.

In some of the studies, students were given a checklist to evaluate their work. Checklist items included "Have I found the most important information that tells me more about the main idea?" and "Does every sentence start with a capital letter?" The teacher then modeled use of the checklist.

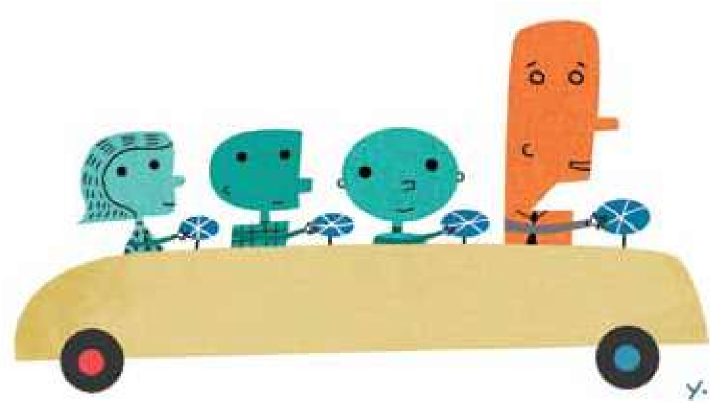
In some studies, students were provided with expert models with which they could compare their work. For example, when students were taught to generate questions, they could compare their questions with those generated by the teacher. Similarly, when learning to write summaries, students could compare their summaries on a passage with those generated by an expert.

9. Require and monitor independent practice: Students need extensive, successful, independent practice in order for skills and knowledge to become automatic.

Research findings

In a typical teacher-led classroom, guided practice is followed by independent practice—by students working alone and practicing the new material. This independent practice is necessary because a good deal of practice (overlearning) is needed in order to become fluent and automatic in a skill. When material is overlearned, it can be recalled automatically and doesn't take up any space in working memory. When students become automatic in an area, they can then devote more of their attention to comprehension and application.

Independent practice provides students with the additional review and elaboration they need to become fluent. This need for fluency applies to facts, concepts, and discriminations that must be used in subsequent learning. Fluency is also needed in operations, such as dividing decimals, conjugating a regular verb in a foreign language, or completing and balancing a chemical equation.



In the classroom

The more successful teachers provided for extensive and successful practice, both in the classroom and after class. Independent practice should involve the same material as the guided practice. If guided practice deals with identifying types of sentences, for example, then independent practice should deal with the same topic or, perhaps, with a slight variation, like creating individual compound and complex sentences. It would be inappropriate if the independent practice asked the students to do an activity such as "Write a paragraph using two compound and two complex sentences," however, because the students have not been adequately prepared for such an activity.

Students need to be fully prepared for their independent practice. Sometimes, it may be appropriate for a teacher to practice some of the seatwork problems with the entire class before students begin independent practice.

Research has found that students were more engaged when their teacher circulated around the room, and monitored and supervised their seatwork. The optimal time for these contacts was 30 seconds or less. Classrooms where the teachers had to stop at students' desks and provide a great deal of explanation during seatwork were the classrooms where students were making errors. These errors occurred because the guided practice was not sufficient for students to engage productively in independent practice. This reiterates the importance of adequately preparing students before they begin their independent practice.

> The best way to become an expert is through practice—thousands of hours of practice. The more the practice, the better the performance.

Some investigators[14] have developed procedures, such as cooperative learning, during which students help each other as they study. Research has shown that all students tend to achieve more in these settings than do students in regular settings. Presumably, some of the advantage comes from having to explain the material to someone else and/or having someone else (other than the teacher) explain the material to the student. Cooperative learning offers an opportunity for students to get feedback from their peers about correct as well as incorrect responses, which promotes both engagement and learning. These cooperative/competitive settings are also valuable for helping slower students in a class by providing extra instruction for them.

10. Engage students in weekly and monthly review: Students need to be involved in extensive practice in order to develop well-connected and automatic knowledge.

Research findings

Students need extensive and broad reading, and extensive practice in order to develop well-connected networks of ideas (schemas) in their long-term memory. When one's knowledge on a particular topic is large and well connected, it is easier to learn new information and prior knowledge is more readily available for use. The more one rehearses and reviews information, the stronger these interconnections become. It is also easier to solve new problems when one has a rich, well-connected body of knowledge and strong ties among the connections. One of the goals of education is to help students develop extensive and available background knowledge.

Knowledge (even very extensive knowledge) stored in long-term memory that is organized into patterns only occupies a tiny amount of space in our limited working memory. So having larger and better-connected patterns of knowledge frees up space in our working memory. This available space can be used for reflecting on new information and for problem solving. The development of well-connected patterns (also called "unitization" and "chunking") and the freeing of space in the working memory is one of the hallmarks of an expert in a field.

Thus, research on cognitive processing supports the need for a teacher to assist students by providing for extensive reading of a variety of materials, frequent review, and discussion and application activities. The research on cognitive processing suggests that these classroom activities help students increase the number of pieces of information in their long-term memory and organize this information into patterns and chunks.

The more one rehearses and reviews information, the stronger the interconnections between the materials become. Review also helps students develop their new knowledge into patterns, and it

(Continued on page 39)

17 Principles of Effective Instruction

The following list of 17 principles emerges from the research discussed in the main article. It overlaps with, and offers slightly more detail than, the 10 principles used to organize that article.

- Begin a lesson with a short review of previous learning.
- Present new material in small steps with student practice after each step.
- Limit the amount of material students receive at one time.
- Give clear and detailed instructions and explanations.
- Ask a large number of questions and check for understanding.
- Provide a high level of active practice for all students.
- Guide students as they begin to practice.
- Think aloud and model steps.
- Provide models of worked-out problems.
- Ask students to explain what they have learned.
- Check the responses of all students.
- Provide systematic feedback and corrections.
- Use more time to provide explanations.
- Provide many examples.
- Reteach material when necessary.
- Prepare students for independent practice.
- Monitor students when they begin independent practice.

–B.R.

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Principles

(Continued from page 19)

helps them acquire the ability to recall past learning automatically.

The best way to become an expert is through practice—thousands of hours of practice. The more the practice, the better the performance.

In the classroom

Many successful programs, especially in the elementary grades, provided for extensive review. One way of achieving this goal is to review the previous week's work every Monday and the previous month's work every fourth Monday. Some effective teachers also gave tests after their reviews. Research has found that even at the secondary level, classes that had weekly quizzes scored better on final exams than did classes with only one or two quizzes during the term. These reviews and tests provided the additional practice students needed to become skilled, successful performers who could apply their knowledge and skills in new areas.

Teachers face a difficult problem when they need to cover a lot of material and don't feel they have the time for sufficient review. But the research states (and we all know from personal experience) that material that is not adequately practiced and reviewed is easily forgotten.

The 10 principles in this article come from three different sources: research on how the mind acquires and uses information, the instructional procedures that are used by the most successful teachers, and the procedures invented by researchers to help students learn difficult tasks. The research from each of these three sources has implications for classroom instruction, and these implications are described in each of these 10 principles.

Even though these principles come from three different sources, the instructional procedures that are taken from one source do not conflict with the instructional procedures that are taken from another source. Instead, the ideas from each of the sources overlap and add to each other. This overlap gives us faith that we are developing a valid and research-based understanding of the art of teaching. ☐

Endnotes

1. *Suggested readings*: George A. Miller, "The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information," *Psychological Review* 63, no. 2 (1956): 81–97; and David LaBerge and S. Jay Samuels, "Toward a Theory of Automatic Information Processing in Reading," *Cognitive Psychology* 6, no. 2 (1974): 293–323.

2. *Suggested readings*: Carolyn M. Evertson, Charles W. Anderson, Linda M. Anderson, and Jere E. Brophy, "Relationships between Classroom Behaviors and Student Outcomes in Junior High Mathematics and English Classes," *American Educational Research Journal* 17, no. 1 (1980): 43–60; and Thomas L. Good and Jere E. Brophy, *Educational Psychology: A Realistic Approach*, 4th ed. (New York: Longman, 1990).

3. *Suggested readings*: Thomas L. Good and Douglas A. Grouws, "The Missouri Mathematics Effectiveness Project," *Journal of Educational Psychology* 71, no. 3 (1979): 355–362; and Alison King, "Guiding Knowledge Construction in the Classroom: Effects of Teaching Children How to Question and How to Explain," *American Educational Research Journal* 31, no. 2 (1994): 338–368.

4. *Suggested readings*: John Sweller, "Cognitive Load Theory, Learning Difficulty, and Instructional Design," *Learning and Instruction* 4, no. 4 (1994): 295–312; Barak Rosenshine, Carla Meister, and Saul Chapman, "Teaching Students to Generate Questions: A Review of the Intervention Studies," *Review of Educational Research* 66, no. 2 (1996): 181–221; and Alan H. Schoenfeld, *Mathematical Problem Solving* (New York: Academic Press, 1985).

5. *Suggested readings*: Evertson et al., "Relationships between Classroom Behaviors and Student Outcomes"; and Paul A. Kirschner, John Sweller, and Richard E. Clark, "Why Minimal Guidance during Instruction Does Not Work: An Analysis of the Failure of Constructivist, Discovery, Problem-Based, Experiential, and Inquiry-Based Teaching," *Educational Psychologist* 41, no. 2 (2006): 75–86.

6. *Suggested readings*: Douglas Fisher and Nancy Frey, *Checking for Understanding: Formative Assessment Techniques for Your Classroom* (Alexandria, VA: Association for Supervision and Curriculum Development, 2007); and Michael J. Dunkin, "Student Characteristics, Classroom Processes, and Student Achievement," *Journal of Educational Psychology* 70, no. 6 (1978): 998–1009.

7. *Suggested readings*: Lorin W. Anderson and Robert B. Burns, "Values, Evidence, and Mastery Learning," *Review of Educational Research* 57, no. 2 (1987): 215–223; and Norman Frederiksen, "Implications of Cognitive Theory for Instruction in Problem Solving," *Review of Educational Research* 54, no. 3 (1984): 363–407.

8. *Suggested readings*: Michael Pressley and Vera Woloshyn, *Cognitive Strategy Instruction that Really Improves Children's Academic Performance*, 2nd ed. (Cambridge, MA: Brookline Books, 1995); and Barak Rosenshine and Carla Meister, "The Use of Scaffolds for Teaching Higher-Level Cognitive Strategies," *Educational Leadership* 49, no. 7 (April 1992): 26–33.

9. *Suggested readings*: Barak Rosenshine, "The Empirical Support for Direct Instruction," in *Constructivist Instruction: Success or Failure?* ed. Sigmund Tobias and Thomas M. Duffy (New York: Routledge, 2009), 201–220; and Robert E. Slavin, *Education for All* (Exton, PA: Swets and Zeitlinger, 1996).

10. *Suggested readings*: Good and Grouws, "The Missouri Mathematics Effectiveness Project"; and James A. Kulik and Chen-Lin C. Kulik, "College Teaching," in *Research on Teaching: Concepts, Findings, and Implications*, ed. Penelope L. Peterson and Herbert J. Walberg (Berkeley, CA: McCutchan, 1979).

11. Good and Grouws, "The Missouri Mathematics Effectiveness Project."

12. These stems were developed by King, "Guiding Knowledge Construction in the Classroom."

13. Sandra J. Berkowitz, "Effects of Instruction in Text Organization on Sixth-Grade Students' Memory for Expository Reading," *Reading Research Quarterly* 21, no. 2 (1986): 161–178. For additional strategies to help students organize material, see Wisconsin Department of Public Instruction, *Strategic Learning in the Content Areas* (Madison, WI: Wisconsin Department of Public Instruction, 2005).

14. Slavin, *Education for All*.

EXPLICIT INSTRUCTION

DIRECT & ENGAGING TEACHING

EXPLICIT INSTRUCTION
EFFECTIVE & EFFICIENT TEACHING

Les leçons interactives rendent l'apprentissage visible afin que les enseignants puissent s'assurer que les élèves apprennent.

ANITA ARCHER & CHARLES HUGHES

DELIVERING INSTRUCTION

COMPÉTENCES EN MATIÈRE D'ENSEIGNEMENT EXPLICITE
L'attention et l'apprentissage des élèves dépendent à la fois de la conception et de l'exécution d'une leçon explicite. Pour être vraiment efficace, l'enseignement doit être interactif.

COMPÉTENCES ESSENTIELLES
- Exiger des réponses fréquentes
- Contrôler les performances de l'élève
- Feedback correctif immédiat
- Dispenser les cours à un rythme soutenu

INPUT → **QUESTION** → **RESPONSE** → **MONITOR** → **FEEDBACK**

INPUT	QUESTION	RESPONSE	MONITOR	FEEDBACK
présenter les informations par petits blocs	l'enseignement interactif - donner du temps de réflexion	susciter une réponse à l'unisson	circuler dans la salle et vérifier la compréhension	la rendre affirmative et corrective

LESSON OPENING

PREVIEW

Énoncer l'objectif de la leçon et discuter de la pertinence de la compétence cible

REVIEW

Revoir les compétences préalables essentielles requises

DEMONSTRATE UNDERSTANDING

LESSON BODY

MODELLING
I do it

MONTRER ET RACONTER
Démontrer la compétence et décrire ce qui est fait en utilisant plusieurs modèles différents.

PENSEZ À L'ÉCOUTE
Utilisez systématiquement un langage pertinent et décrivez uniquement les actions clés.

DEMONSTRATE UNDERSTANDING

GUIDED PRACTICE
We do it

RÉDUIRE L'INCITATION
Incitations physiques, verbales et visuelles.

RÉDUIRE L'ÉCHAFAUDAGE
Dire aux élèves ce qu'ils doivent faire
Demander aux élèves ce qu'ils doivent faire
Leur rappeler ce qu'ils doivent faire

DEMONSTRATE UNDERSTANDING
HIGH RATES OF ACCURACY

UNPROMPTED PRACTICE
You do it

Les élèves s'exercent sans être guidés par l'enseignant :

-Présenter des problèmes ou des tâches similaires
-Les élèves complètent un élément à la fois
-Vérifier les réponses et fournir un retour d'information après chaque élément

DEMONSTRATE UNDERSTANDING
HIGH RATES OF ACCURACY

LESSON CLOSING

REVIEW

Impliquer les étudiants dans la révision du contenu critique couvert

PREVIEW

Prévisualiser le contenu de la prochaine leçon

ASSIGN

Assigner un travail indépendant si les élèves en sont au bon stade.

THROUGHOUT THE LESSON: INVOLVE STUDENTS. MONITOR PERFORMANCE. PROVIDE FEEDBACK.

INDEPENDENT PRACTICE

DÉVELOPPER LA FLUIDITÉ
La recherche montre que pour atteindre la compétence, la pratique et le retour d'information sur la qualité de cette pratique sont nécessaires. Concentrez-vous sur les compétences, les concepts et les règles qui sont inconnus des élèves et qui sont essentiels à leurs résultats scolaires. Intégrez des séances de pratique délibérée dans vos cours, répartissez les séances de pratique d'une compétence dans le temps et testez les connaissances avec des tâches de récupération fréquentes.

DELIBERATE PRACTICE

garantir des niveaux élevés de précision, puis mettre en place une pratique de masse immédiate

DISTRIBUTED PRACTICE

espacement de courtes séances de pratique d'une compétence au fil du temps

RETRIEVAL PRACTICE

tester les connaissances dans des conditions à faible enjeu et mélanger les stratégies

SUSCITER DES RÉPONSES FRÉQUENTES
La participation active vise à impliquer tous les élèves en leur donnant la possibilité de réagir de manière structurée, que ce soit par la parole, l'écrit ou l'action. En répondant, les élèves récupèrent, répètent et mettent en pratique les informations, les concepts, les compétences ou les stratégies enseignés. Susciter des réponses, en présentant quelques informations avant de s'arrêter pour demander une réponse - cela permet de responsabiliser les élèves.

ACTION RESPONSES

Hand Signals *put up number of fingers for answer*
Acting Out *physically show solid, liquid, gas*
Gestures

WRITTEN RESPONSES

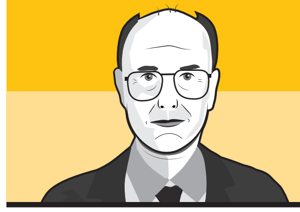
Mini-whiteboards
Response Cards *yes/no, T/F*
Hinge Questions
Exit Tickets
Written Summary

ORAL RESPONSES

Choral Response *everyone say it together in unison*
Think, Pair, Share
Cold Calling
Random Name Generator

Designed by **JAMIE CLARK |** XpatEducator

Reference: 'Cognitive Load Theory: Research That Teachers Really Need To Understand: Classroom Practice Guide'.
Centre For Education Statistics and Evaluation, 2017.



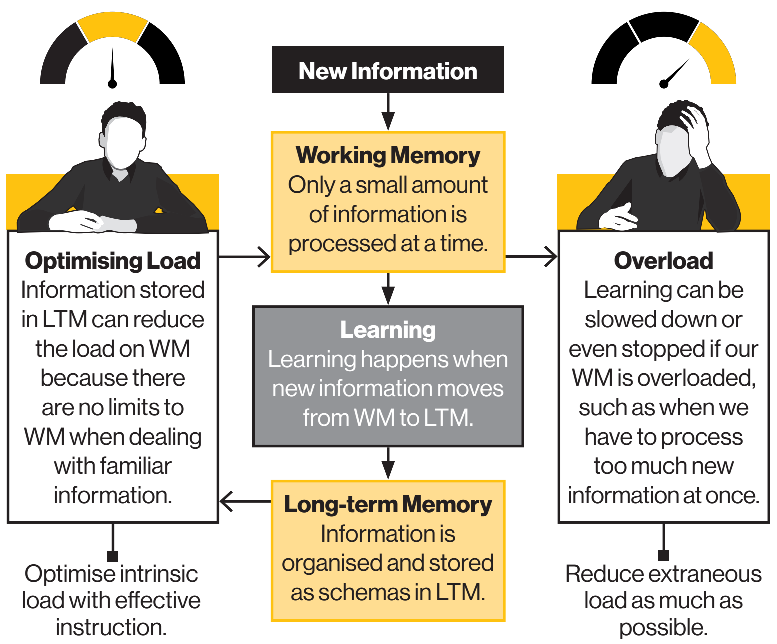
John Sweller et al.

Cognitive Load Theory

Six Strategies to Tailor Instruction for Maximum Learning

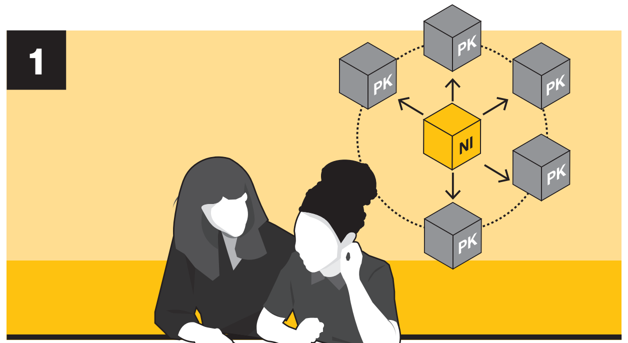
ADAPTER L'ENSEIGNEMENT POUR UN APPRENTISSAGE MAXIMAL
La théorie de la charge cognitive (CLT) explore la manière dont la charge cognitive, ou l'effort mental, nécessaire pour traiter l'information a un impact sur l'apprentissage. Pour apprendre quelque chose de nouveau, les connaissances doivent d'abord être traitées dans la mémoire de travail avant d'être transférées et stockées dans la mémoire à long terme sous la forme de "schémas". Si la mémoire de travail est surchargée, il y a plus de risques que le contenu enseigné ne soit pas compris par l'apprenant. Cette connaissance du cerveau humain est essentielle pour les enseignants, car elle permet de concevoir des stratégies d'enseignement qui libèrent et optimisent la charge de la mémoire de travail des étudiants afin de maximiser l'apprentissage. Le CLT soutient l'utilisation de l'enseignement explicite (en particulier pour les apprenants débutants). Les recherches montrent que des conseils directs et explicites sont plus efficaces et efficients pour enseigner de nouveaux contenus et compétences aux débutants.

How the Human Brain Learns

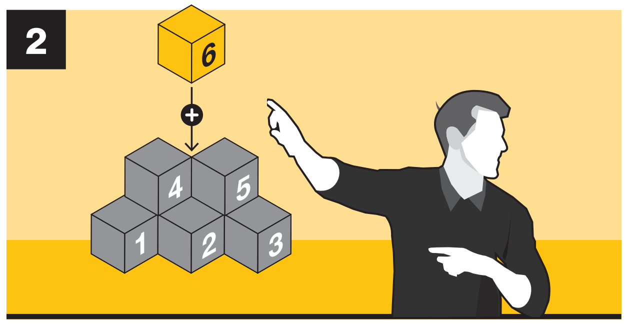


The Two Types of Cognitive Load

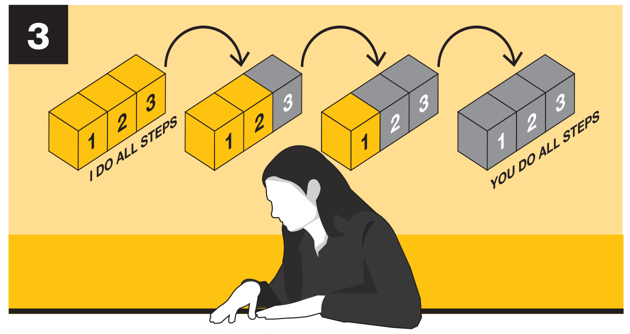
Reduce Extraneous Load and Optimise Intrinsic Load
CLT identifies two main types of cognitive load: intrinsic and extraneous. Intrinsic cognitive load relates to the inherent difficulty of the subject matter being learnt. We must optimise intrinsic load by responding to and adjusting the difficulty of the learning content. Extraneous cognitive load relates to *how* the subject matter is taught. Extraneous load is the 'bad' type of cognitive load, because it does not directly contribute to learning and therefore must be reduced.



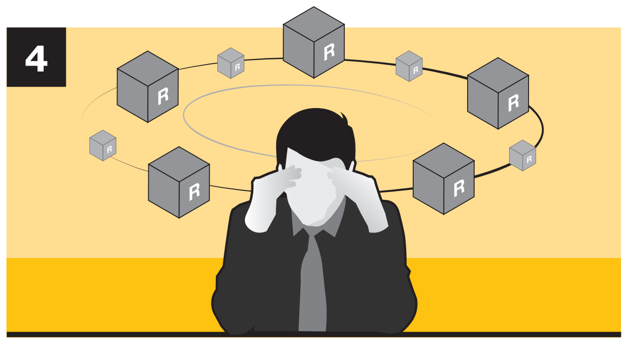
S'APPUYER SUR LES CONNAISSANCES ANTÉRIEURES DES ÉLÈVES
Adapter les cours aux connaissances existantes des élèves est cruciale pour un apprentissage optimal. En ajustant la complexité des tâches en fonction des capacités des élèves et en minimisant la charge cognitive, vous pouvez maximiser les résultats de l'apprentissage. Vous pouvez activer les connaissances antérieures des élèves en reliant les nouvelles informations à ce qu'ils savent déjà par des analogies, des exemples du monde réel, ou en comparant et en opposant des idées familières.



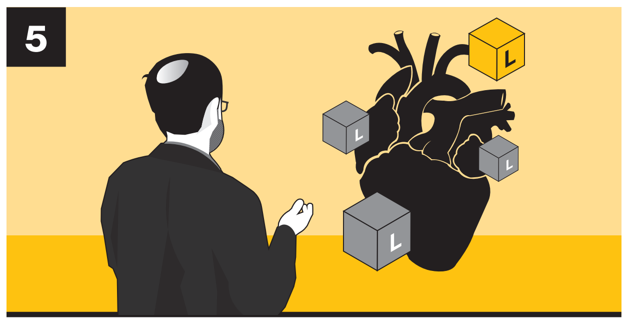
EXEMPLES RÉSOLUS POUR ENSEIGNER UN NOUVEAU CONTENU
Un "exemple résolu" est un problème qui a déjà été résolu pour l'élève et dont toutes les étapes ont été expliquées et montrées clairement. Les recherches démontrent que les élèves qui reçoivent de nombreux exemples résolus apprennent un nouveau contenu plus efficacement que les élèves qui doivent résoudre eux-mêmes le même problème. La résolution de problèmes sans aide peut surcharger la mémoire de travail et, par conséquent, avoir un impact sur le transfert des connaissances vers la mémoire à long terme. Les exemples résolus sont plus efficaces lorsqu'ils sont combinés avec la réflexion à haute voix de l'enseignant afin d'externaliser le processus de pensée.



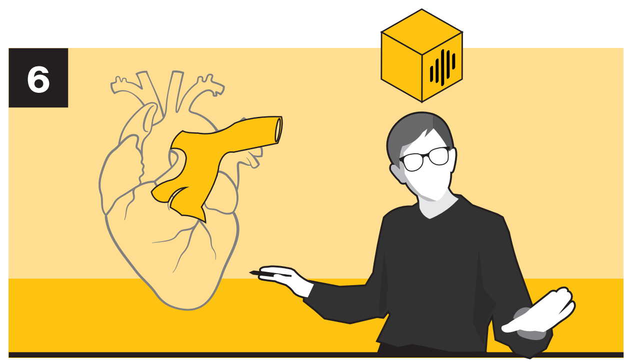
AUGMENTER L'AUTONOMIE
Un enseignement entièrement guidé est efficace pour enseigner de nouvelles matières, mais à mesure que les élèves acquièrent des compétences, il devient contre-productif. Trop d'accompagnement peut surcharger la mémoire de travail. La résolution autonome de problèmes est plus bénéfique à mesure que les élèves développent leur expertise. Pour y parvenir efficacement, surveillez les connaissances et les compétences des élèves, et adaptez vos stratégies d'enseignement en conséquence à mesure que les élèves deviennent progressivement plus compétents. Cela peut signifier omettre certaines étapes d'un exemple résolu (également appelé « tâche à compléter ») ou donner progressivement moins d'exemples résolus aux élèves.



SUPPRIMEZ LES INFORMATIONS INUTILES
Pour améliorer l'apprentissage et réduire toute charge cognitive inutile sur la mémoire de travail des élèves, il est essentiel d'éliminer les informations non essentielles. Cela signifie que les supports pédagogiques doivent être aussi simples que possible et ne pas répéter les mêmes points de différentes manières. Dans les présentations multimédias, envisagez de répartir les nouvelles informations sur plusieurs diapositives, de verbaliser le texte au lieu de l'afficher et d'omettre les images non pertinentes. Gardez à l'esprit que ce qui est essentiel pour les débutants peut devenir superflu pour les apprenants plus avancés, et adaptez le contenu en fonction de leur expertise croissante.



PRESENTEZ LES INFOS ESSENTIELEES ENSEMBLES
Une surcharge cognitive peut se produire lorsque les élèves doivent répartir leur attention entre deux ou plusieurs sources d'informations qui ont été présentées séparément, mais qui ne peuvent être comprises qu'en référence les unes aux autres (par exemple, un diagramme scientifique). Les données disponibles suggèrent que cette séparation a des conséquences négatives et devrait être éliminée dans la mesure du possible. Dans cette optique, les enseignants devraient concevoir des supports pédagogiques qui intègrent des étiquettes, incorporent des instructions écrites à côté des tâches et utilisent des repères visuels pour mettre en évidence les informations clés sur les feuilles de travail et autres ressources pédagogiques.



DONNEZ L'INFO VERBALEMENT ET VISUELLEMENT
L'« effet de modalité » désigne la stratégie consistant à utiliser à la fois les modes de communication auditif et visuel afin de réduire la charge cognitive. Selon la théorie du double codage, notre mémoire de travail dispose de deux canaux. L'un pour traiter les informations visuelles et l'autre pour traiter les informations auditives. L'« effet de modalité » exploite les deux canaux de la mémoire de travail pour augmenter sa capacité. Pour ce faire, les enseignants peuvent verbaliser les informations au lieu de les présenter aux élèves pour qu'ils les lisent et les entendent. Par exemple, lorsque vous présentez un diagramme, utilisez uniquement des repères visuels (tels que des pointeurs), puis expliquez les étiquettes à l'aide de votre voix.