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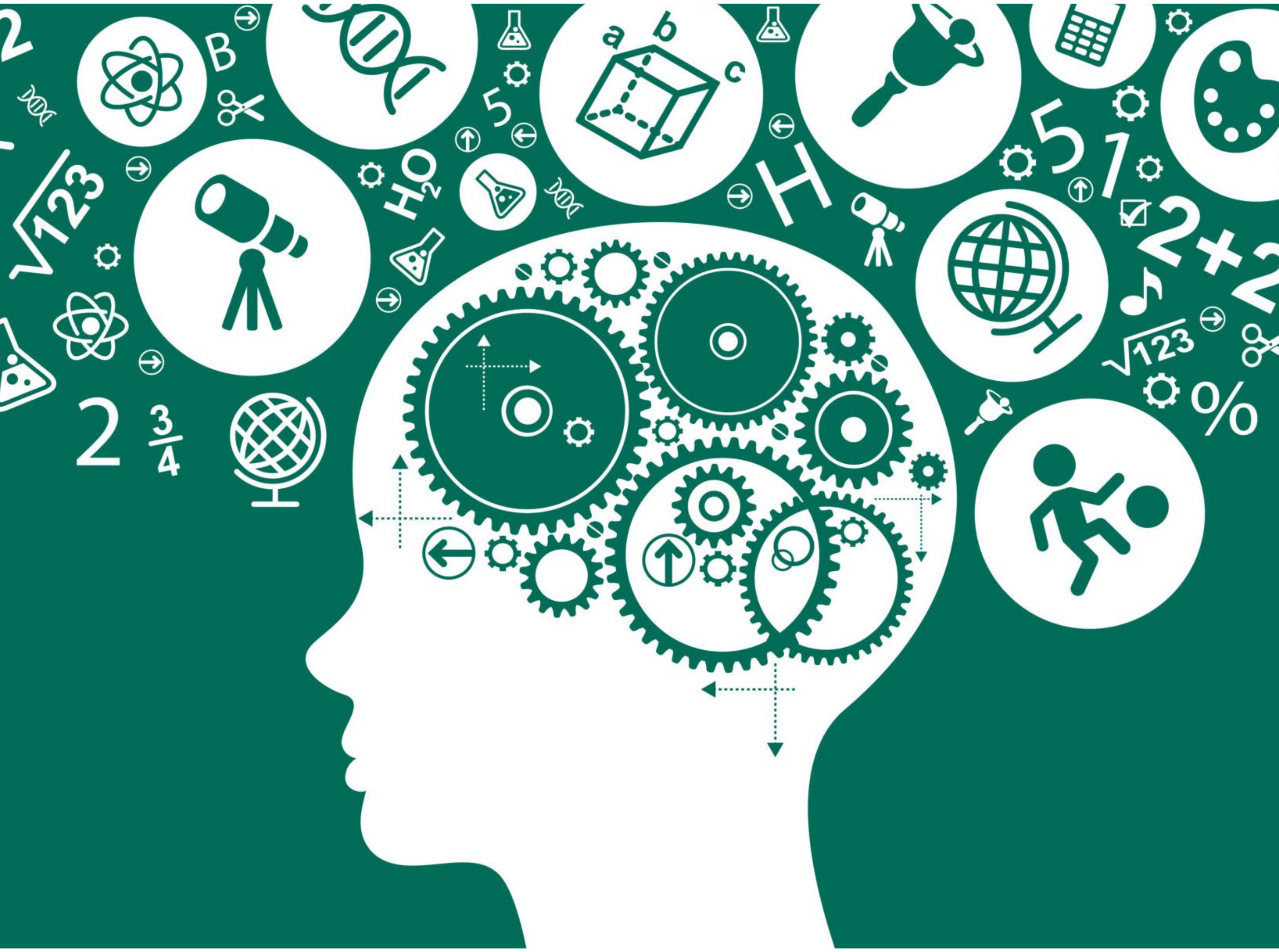
STUDIES

Analysis Paper 24
August 2021

CIS Education Program



Why Inquiry-based Approaches Harm Students' Learning

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Contents

Executive Summary

- Australia's rankings on international tests such as the Program for International Student Assessment (PISA) have been falling for many years in most curriculum areas. Those falls have been concurrent with an increased emphasis on inquiry learning, discovery learning, problem-based learning (the terms are indistinguishable) and critical thinking in Australian curricula.
- Inquiry learning places an increased emphasis on learners discovering information for themselves rather than having the information explicitly presented to them. This paper suggests a causal relation between the emphasis on inquiry learning and reduced academic performance.
- Inquiry learning was conceived six decades ago based on assumptions that flowed from our understanding of human cognition at that time. Subsequently, it became increasingly popular despite very limited empirical evidence for its efficacy. Simultaneously, with the considerable expansion of our knowledge of human cognition, it has become increasingly difficult to reconcile that new knowledge with the use of inquiry-based learning.
- There are two broad categories of information. Biologically primary information consists of information that we have specifically evolved to acquire. It is associated with generic-cognitive skills such as the ability to use general problem-solving strategies. We acquire biologically primary skills unconsciously and effortlessly without tuition. They do not need to be taught and are acquired automatically because we have evolved to acquire them. Biologically secondary information includes knowledge that we consider to be culturally important but have not specifically evolved to acquire. Most commonly it consists of domain-specific skills such as how to solve particular types of problems that we learn with conscious mental effort. Schools were invented to teach domain-specific, biologically secondary skills.
- We are able to acquire biologically secondary information slowly and with considerable effort via inquiry learning but can also acquire it far more rapidly and easily via explicit instruction from other people, such as teachers.
- Once novel information has been acquired, it is processed by a working memory that is severely capacity- and duration-constrained, before being transferred to and stored in a large, long-term memory that has no known capacity or duration limits. When faced with appropriate environmental signals, stored information can be transferred back to working memory to generate appropriate action. Working memory has no known capacity or duration limits when it deals with familiar information transferred from long-term memory. That change in the characteristics of working memory when dealing with novel compared to familiar information explains the transformative effects of education.
- Cognitive load theory is an instructional theory based on this cognitive architecture. Using randomized, controlled trials, empirical work flowing from the theory provides considerable evidence for the advantages of explicit instruction over inquiry-based learning. Other work, using correlational studies, has found that the more inquiry-based learning is used in a classroom, the lower the students' test scores.
- Based on both theory and data, there is little justification for the current emphasis on inquiry learning.

Introduction

Historically, the idea of inquiry-based learning began 60 years ago with the cognitive psychologist Jerome Bruner,[1] who introduced the term 'discovery learning'; a term now rarely used. Instead, it is referred to by completely interchangeable terms: 'problem-based learning', 'constructivist learning' and (most commonly today) 'inquiry learning' — the term this paper will use.

Bruner was one of the founders of cognitive psychology and so, unsurprisingly, his concept of learning via inquiry was centred on our knowledge of cognitive psychology at that time. Based on that relatively rudimentary knowledge, Bruner's theory and recommended practice were entirely rational. As a consequence, within two to three decades it was dominant, indeed, all-pervasive in educational circles with minimal opposition. Until recently, that situation persisted, especially in Anglosphere countries.

A justification for using inquiry learning is that humans are problem-solving animals. Our ability to solve complex problems is a major differentiator between us and other species, and humans' soaring heights of creativity over the millennia attest to the importance of an inquiring mind. Traditionally, education has placed little emphasis on problem-solving and creativity. Nevertheless, it is very easy to assume that if students are taught how to think and solve problems, it should have entirely positive effects. Accordingly, placing an emphasis on inquiry learning in classrooms should increase students' ability to solve novel problems in a creative fashion with commensurate advantages to society in general.

So the suggestion that inquiry learning would increase learners' general problem-solving and thinking skills seemingly made sense. We need to practise to be skilled at anything and so why should practice at general problem solving not increase general problem-solving skills? It was believed that if students learn via inquiry, that practice of problem solving should surely increase problem-solving skills; just as practice at writing, arithmetic, tennis or anything else increases a skill. Hence, the suggestion was enthusiastically adopted by the field.

The proposed advantages of inquiry learning did not stop at increasing general problem-solving skills and creativity. Compared with simple memorisation, inquiry learning was posited as a superior way of learning the concepts and procedures associated with any discipline. Discovering mathematical, science, or historical facts, concepts or procedures during inquiry learning should result in that knowledge being better learned and being better able to be applied to new facts, concepts and procedures. That is how such knowledge is acquired by researchers. Furthermore, that is how knowledge is acquired by all of us in the real world outside of education and training institutions. We find it much easier and more interesting to acquire our knowledge by investigating in the real world compared with the difficult and boring way we have to acquire knowledge in classrooms by listening to a teacher, reading a textbook or reading from a screen. Inquiry learning is natural and if it is imported into schools, it was believed that learning in classrooms should be just as effective as learning in the external world. Accordingly, as well as increasing our problem-solving skills, inquiry learning should increase our subject-matter knowledge.

On both these grounds, that students need to be taught how to inquire so that their general problem-solving skills improve, and that they will learn everything else more effectively through inquiry rather than any alternative method, the argument was compelling. It is clear, rational, and very easy to understand. Alternative views were swept away.

Critically, the support for inquiry-based learning most commonly comes from people with little familiarity with advances in our knowledge of human cognition. When considering a topic such as inquiry learning, knowledge of human cognitive architecture — how we learn, think and solve problems — is critical because the concept of inquiry learning with its emphasis on problem solving is a psychological concept.

However, over the decades, as our knowledge of human cognitive architecture advanced, it has become increasingly clear that the advances did not favour inquiry learning. Furthermore, as data from randomised, controlled trials, as well as from correlational studies, began to appear, those data were equally problematic for an inquiry learning perspective. I'll begin by outlining those aspects of human cognitive architecture relevant to instructional issues.

Human Cognitive Architecture

Much of what we now know of human cognitive architecture is associated with the relatively new discipline of evolutionary psychology. Cognitive load theory,[2] an instructional theory based on our knowledge of evolutionary psychology and on human cognitive architecture, provides the source for what follows.

Evolutionary Psychology and Categories of Knowledge

Information can be categorised in multiple ways, with most categories being irrelevant to instructional design issues. If an instructional procedure has the same effects on learning irrespective of the category of information, then that particular categorisation scheme is irrelevant to instructional issues, although it may be important for other reasons. Evolutionary educational psychologist David Geary categorised knowledge into biologically primary and secondary knowledge[3] — two categories that have profound instructional design consequences, including the issue of inquiry learning.

Biologically primary knowledge is knowledge we have evolved to acquire over many generations. Examples include: learning to listen to, and speak, our native language; acquiring generic problem-solving skills; learning to interact socially with other people; and learning to generalise from one situation to another similar situation. Biologically primary knowledge is modular, in that one primary skill may have limited or no relation to another skill. Both skills may have evolved in entirely different evolutionary epochs resulting in limited or no relation to each other. For example, we may have evolved to use spoken language much later than we evolved to generalise from one situation to another.

Biologically secondary knowledge and skills relate to information that has become culturally important to us. We can acquire secondary information but we have not specifically evolved to acquire any particular example of secondary information. Examples of secondary information can be found in almost any of the curricula taught in educational and training institutions; from learning to read and write to learning mathematics, science and history. We invented schools and training institutions in order to assist students to acquire biologically secondary knowledge. Without schools or personal tuition, most people will fail to acquire most biologically secondary skills. In contrast, schools are not needed to acquire biologically primary skills, which will be acquired irrespective whether a person attends an educational institution.

Most biologically primary information consists of generic-cognitive knowledge such as learning a general problem-solving strategy or learning to self-regulate our mental processes.[4] Generic-cognitive skills apply to a large range of different problems. Learning a general problem-solving skill can apply to, for example, solving any mathematics problem, completing a jigsaw puzzle, or finding one's way around a new location. A means-ends strategy,[5] which can be used to solve all of the above problems, requires a problem solver to consider their current problem state, consider the goal state, find differences between the current problem state and the goal state, and find problem operators that can be used to reduce those differences. Using a means-ends strategy is generic-cognitive knowledge that is unteachable because we have evolved to acquire it as a biologically primary skill.

While the use of a means-ends strategy may appear a simple task, it only appears simple precisely because it is a biologically primary task that we have evolved to acquire. Programming a means-ends strategy using early artificial intelligence proved anything but simple.

In contrast to the generality of biologically primary information, biologically secondary information tends to be very domain specific. An example of a domain-specific, biologically secondary skill is knowing that the best first move when solving a problem such as, *$(a + b)/c = d$, solve for a,* is to multiply out the denominator. We have not evolved to learn this domain-specific, problem-solving strategy that applies only to this and similar problems. Importantly, it is a biologically secondary skill that we will not normally acquire without education.

Biologically primary and secondary knowledge are acquired differently. While primary knowledge is frequently immensely complex, it is acquired relatively easily, automatically and without conscious effort despite its complexity. We do not need to be taught general problem-solving procedures nor do we need to figure out how to acquire and use general problem-solving strategies. Most of us could not describe the strategies we use or explain how we acquired them, because their acquisition and use is entirely unconscious. Teaching them is pointless because in the normal course of events, they will be acquired anyway. We have evolved to acquire and use general problem-solving strategies because they are essential to our survival.

Biologically secondary knowledge has a very different acquisition footprint. We do not acquire secondary knowledge unconsciously, automatically or effortlessly. It requires conscious effort on our part and frequently requires assistance through tuition from others. Without that conscious effort from both the learner and teacher, learning of biologically secondary information may be difficult or even absent.

The differences between generic-cognitive, biologically primary information and domain-specific, biologically secondary information have direct relevance to the inquiry learning debate. Prior to that distinction being made, it was perfectly sensible to argue that (a) we obtain enormous amounts of information outside education easily and automatically without explicit instruction, and (b) if we were to apply the same natural procedures to information within education, learning should be equally straightforward and equally effective. It follows that learning should be facilitated by the use of inquiry learning. Furthermore, the human genius manifests itself through inquiry; and this seemingly provides another reason to emphasise inquiry learning in education.

However, this rationale for inquiry learning becomes irrelevant if the real distinction between school-based learning and real-world learning is not the instructional techniques used but rather, the relevant categories of information. Once we understand that school-based learning deals with an entirely different category of information to most of the information dealt with in the outside world, the rationale for attempting to use the same instructional techniques in both contexts disappears.

To be effective, inquiry learning must either enhance our ability to inquire, i.e., enhance general problem-solving skills, or enhance our ability to acquire domain-specific knowledge compared with alternative teaching techniques. Attempting to enhance general problem-solving skills such as inquiry is likely to be difficult or impossible if the ability to inquire is biologically primary and so ingrained. There is no point emphasising skills that have already been acquired as part of the human condition. Of course, while we may all be able to engage in inquiry because it is biologically primary, if teaching techniques emphasise inquiry they may assist in the acquisition of the domain-specific, biologically secondary information that is studied in schools. Whether or not inquiry-based learning is the best way of acquiring domain-specific, biologically secondary knowledge is an empirical question considered next.

Cognitive Architecture Associated with Biologically Secondary Information

The cognitive architecture associated with biologically secondary information differs from the architecture associated with biologically primary information. When dealing with education, we are mainly concerned with the architecture associated with the acquisition of biologically secondary information. That architecture can be described by five principles: two principles dealing with the acquisition of novel information; two dealing with the processing and storage of information for later use; and one dealing with the use of familiar information to generate appropriate action. Each of these principles refers to a biologically primary skill that is used to acquire biologically secondary knowledge. None of the principles need to be taught, because they are part of our evolved attributes.

The first two principles are concerned with the two ways we can obtain novel information. The first principle is concerned with how we can generate novel information during problem solving — in other words, during inquiry learning. In the absence of knowledge, the only way we can generate effective problem-solving moves is by using a 'random generate and test' procedure. We can use knowledge to constrain the potential number of moves we test but once knowledge is exhausted, random generation of moves is the only procedure available to us. Once a problem-solving step is made, we can test it for effectiveness; with effective steps that move us closer to our goal retained and ineffective steps discarded.

The second principle is concerned with the second way we can obtain novel information. As well as generating novel information during problem solving as indicated by the first principle, we also can obtain novel information by borrowing it from other people. Information is borrowed from others by listening to what they say, reading what they write or imitating them. As a species, we are better than any other in obtaining information from each other. Our unparalleled ability to obtain information from each other is likely to be a major reason for our success as a species.

The differences between these two procedures for obtaining novel information are critical to the inquiry learning debate. The first point to note is that obtaining information from others is vastly more efficient than obtaining it during problem solving. A problem that we either cannot solve or that would take us weeks or months to solve may be soluble in seconds if someone shows us how to solve it. We might expect that explicit instruction should facilitate learning compared with inquiry learning or problem solving. The worked example effect, discussed next, derived from cognitive load theory demonstrates precisely this result.

The worked example effect is demonstrated by randomised, controlled trials in which one group of students is presented a series of problems to solve while another group is presented the same problems along with their detailed solutions. Both groups are then given a common problem-solving test. Dozens of experiments from across the globe have demonstrated superior problem-solving performance on a test by the worked examples group.[6] Given this result, it is difficult to see a justification for any suggestion that inquiry-based learning facilitates the acquisition of knowledge.

Why should explicit instruction such as the use of worked examples be superior to inquiry-based learning? An answer to this question is provided by the manner in which we process and store novel information, an issue covered by the third and fourth principles of human cognitive architecture. Whether novel information is generated during problem solving or whether it is obtained from other people, it must be processed by working memory. That structure, which is the subject of the third principle, is critical to human cognition and critical to instructional design. It also should be critical in decisions to use inquiry learning but is almost never mentioned in curriculum documents that advocate the use of inquiry learning-based instruction.

When processing novel information, and only when processing novel information, working memory has two peculiar characteristics. It is extremely limited in both capacity and duration.

With respect to capacity, working memory can only hold about 7 items of information[7] and process about 3-4 items of information[8] — where processing means combining, contrasting, or manipulating the items in some manner. For example, you can remember about 7 random digits but if you are asked to re-order them from highest or lowest, the number of digits for which you can successfully complete the task is less than 7. A novice algebra student who is unfamiliar with algebraic symbols may be able to memorise the equation $(a + b)/c = d$ with some difficulty but is unlikely to be able to manipulate it mentally when solving a problem.

With respect to duration, we can hold novel information in working memory for a few seconds without mentally rehearsing it. After about 20 seconds, almost all of the information is lost. If we want to work on novel information, we need to either write it down or keep rehearsing it until it is no longer needed. To make everything even worse, there is now evidence that working memory depletes with use before recovering with rest.[9]

These limitations of working memory are universal and central to instruction. By definition, learners are being asked to deal with novel, unfamiliar information. Inquiry learning and problem-solving activities — indeed, any instructional activity that unnecessarily increases working memory load — will inevitably have deleterious consequences. The evidence that explicit instruction such as studying worked examples facilitates learning, compared with less direct instructional procedures such as problem solving, is overwhelming from both theoretical and empirical grounds. From a theoretical perspective, studying worked examples should reduce unnecessary working memory load compared with solving problems. Empirically, that result is found.

Once information has been processed in working memory, it can be transferred to long-term memory for permanent storage. Long-term memory is the subject of the fourth principle. While working memory limitations can be surprising, the lack of limitations of long-term memory can be equally surprising along with the nature of the information stored in long-term memory. We tend to think of long-term memory as being a repository of random, unrelated facts that have little relevance to complex thought. While long-term memory can store rote-learned, unrelated snippets of information, that is not its primary function. Its primary function is to store enormous numbers of complex units of closely linked information. In a very real sense, our sense of self comes from that enormous amount of information stored in long-term memory.

The critical role of long-term memory in thought came from a surprising source — the game of chess. We all supposedly 'know' that chess is a game of thinking and problem solving. It seems that we may be wrong: chess turns out to be a game of memory. The critical work was carried out by Dutch psychologist (and chess Olympian) Adrianus De Groot,[10] who initially published his work in Dutch in the late 1940s. It gained an international audience after later publication in English.

De Groot wanted to know why chess masters always defeat less able, week-end players. Initial hypotheses — for example, that chess masters are able to consider a greater range of moves at each point in the game than less able players or consider a greater number of moves ahead in the game — proved to be a dead-end. Chess masters did not consider a greater range of possible moves than less able players and so their ability to pick better moves was not due to them considering more moves. De Groot found only one difference between less and more able players. When shown a chess board configuration taken from a real game for 5 seconds, chess masters were able to reproduce the configuration from memory with over 80% accuracy. Less able players had an accuracy rate of less than 30% on the same task.

American psychologists William Chase and Herbert Simon[11] later replicated these results and, in addition, found that if the same experiment was conducted using random chess board configurations, the difference between less and more able players disappeared — with everyone able to replace few of the pieces on the board from memory. The difference between player levels in memory of board configurations occurred only for configurations taken from real games, not for any board configuration. Whatever the reason for the increased memory of board configurations taken from real games, it was not due to differences in working memory, since those differences should apply to any board configuration.

The game of chess has little educational interest, of course, but similar results have been obtained in a wide range of educationally relevant areas from mathematics, computer science and social science.[12] What do these results mean for cognitive processes and instructional design? Long-term memory is central to our cognitive processes. It is not just a minor, cognitive structure intended to hold trivial, random information. It is central to our ability to think and solve problems. During the many years of practice it takes us to become competent in a substantial domain, we memorise a countless number of problem states and the best moves to make when encountering those states. That enormous store of knowledge, held in long-term memory, determines our skill in any domain.

The immense size of our long-term memory store can be surprising. The reason it is surprising is that we are unaware of the contents of long-term memory. We only are conscious of the contents of working memory and indeed, consciousness can be defined as the contents of working memory. Those contents are a tiny fraction of the entirety of long-term memory. How and why we transfer information from long-term to working memory is the subject of the fifth and last principle.

Once information has been created during problem solving or borrowed from someone else, processed by working memory and then stored in long-term memory, it is ready for its final and most important function, the function for which the previous four principles exist. The fifth and last principle is concerned with generating action appropriate for the extant environment. Based on environmental signals, information stored in long-term memory can be transferred back to working memory to generate action. For example, if you have stored information in long-term memory allowing you to recognise problems like, *(a + b)/c = d, solve for a,* along with the solution to the problem, when you see this or a similar problem, you can transfer the relevant information from long-term memory to working memory, providing you with an immediate problem solution.

It was indicated when discussing the third principle that working memory is very limited in capacity and duration when dealing with novel information. However, those limits disappear when dealing with previously organised information that has been stored

Table 1: Human cognitive architecture processing domain-specific, biologically secondary information

Principle	Characteristics	Consequences
1. Generating novel information during problem solving	Provides the initial source of all novel information from the external environment. Relies on random generate and test during problem solving.	A very slow and inefficient way of obtaining novel information. Reduces learning when used during inquiry learning.
2. Obtaining novel information from other people	A vastly more efficient method of obtaining novel information than problem solving.	The most efficient way of acquiring novel information and should be used in educational contexts.
3. Working memory when processing novel information	Once obtained from the external environment, novel information is processed by a severely limited capacity and duration working memory.	The limitations of working memory explain why generating novel information by problem solving is so difficult and why there is such a large increase in efficiency associated with obtaining information from other people.
4. Storing novel information in long-term memory	Information that has been processed by working memory can be transferred for permanent storage in long-term memory for later use. Long-term memory has no known capacity or duration limits.	The enormous size of long-term memory compensates for the limitations of working memory. Differences in expertise in a given area are due to differences in the contents of long-term memory. The ultimate aim of education is to increase the contents of long-term memory.
5. Transferring familiar information from long-term to working memory to govern appropriate action	On receipt of environmental signals, information stored in long-term memory can be transferred as familiar information back to working memory. Working memory has no known capacity or duration limits when dealing with familiar information from long-term memory.	The transformation of working memory from a limited capacity and duration structure when dealing with novel information from the external environment, to an unlimited structure when dealing with familiar information from long-term memory, explains the transformative effects of education.

in long-term memory. If working memory has limits when dealing with organised information from long-term memory, we do not know where they are. The elimination of working memory limits when dealing with familiar, biologically secondary information provides the ultimate justification for the human cognitive system. We are transformed by knowledge. Indeed, it is a truism to say that education transforms us. The machinery of the human cognitive system as summarised here and in Table 1, explains how.

What is the role of inquiry learning in this system? According to the first principle, we can — and do — learn by problem solving. Indeed, all biologically secondary knowledge had to be initially created during problem solving, because there was no one available from whom we could borrow the information via the second principle. But we only use problem solving when we have no alternative. There is no intrinsic value to problem solving, a biologically primary activity, other than to provide us with information that would otherwise be unavailable to us. In an education context, alternative sources of information are always available and, as is the case with problem solving, borrowing information from others is biologically primary and vastly more efficient than problem solving. Using problem solving and inquiry learning as a teaching tool is a recipe for inefficient, ineffective learning.

Cognitive Load Theory

This cognitive architecture provides the base for cognitive load theory[13] — an instructional theory that uses the above cognitive architecture to generate novel instructional effects. Each instructional effect is based on randomised, controlled trials comparing a new instructional procedure with a commonly used procedure. The ultimate aim is to provide instructional prescriptions with the criterion for success being the ability of the theory to provide those prescriptions.

The worked example effect described above is one of the instructional effects generated by the theory. It is not the purpose of this paper to describe the details of the theory or the instructional effects generated by the theory. Those details can be found in the theory's many summaries, some of which are listed in the previous paragraph. The worked example effect was described because it is directly pertinent to the issue of inquiry learning and a comparison between problem solving and explicit instruction.

Here is a summary of why studying worked examples is superior to solving the equivalent problems. Consider a learner who is asked to solve a problem such as: *For the equation, $(a + b)/c = d$, solve for a,* compared to a learner who is asked to study a worked example such as:

For the equation, $(a + b)/c = d$, solve for a.

$(a + b)/c = d$

$a + b = dc$

$a = dc - b$

Problem solving requires learners to generate information using the first principle rather than obtaining information from others in accord with the second principle. In contrast, studying worked examples uses the second rather than the first principle. We know it is vastly more efficient to obtain information from others using the second principle than to generate it ourselves using the first principle. The reason it is more efficient is because of the limitations of working memory when dealing with novel information. Solving a novel problem requires learners to:

- consider where they are now in the problem (e.g. $a + b = dc$);
- consider the goal of the problem ($a = ?$);
- extract differences between the two (*there is a "b" on the left hand side that needs to be removed)*;
- find a move to reduce those differences (subtract *"b"* from both sides of the equation); and
- keep track of where they are in relation to the entire problem.

For a novice just beginning to learn algebra, the working memory load can be overwhelming. In contrast, studying a worked example eliminates this process entirely because all of the moves are laid out by the worked example. Working memory can be used to understand and learn how the problem is solved instead of attempting to find appropriate moves.

There have been a large number of studies demonstrating the worked example effect in a variety of curriculum areas. For example, the effect has been demonstrated in mathematics,[14] science,[15] English literature,[16] visual arts,[17] and law,[18] along with many other studies in a variety of areas.

There is one other effect — the expertise reversal effect[19] — that also needs to be discussed because of its relevance to inquiry learning. Consider a student learning to solve a new set of problems in a particular domain. As indicated above, learning will be facilitated by providing the student with a set of worked examples to study rather than the equivalent problems to solve, leading to the worked example effect. We know that learning does not cease once the student has understood the problem solution.

A student may have understood the procedure for multiplying out the denominator in an equation such as $a/b = c$, in order to solve for a, but if that procedure is to be used as a move to solve complex problems, it must be automated by continued practice. If a learner has to stop and think "I have to get rid of the *b* on the left side of this equation. How do I do that? Subtract *b* from both sides? No, that will not work. I know, I should multiply both sides by *b* to give me $(a/b)b = cb$. By cancelling *b* on the left side, leaving me with $a = cb$, I can solve for *a*."

That process requires working memory resources and since we are dealing with a novice in this area, those resources are in short supply. Expecting the student to solve a complex problem using this procedure is likely to be optimistic. If in contrast, like most readers of this paper, the student has automated the process and knows immediately that if $a/b = c$, then $a = cb$ without having to think about it, there is a greater likelihood of that student having sufficient working memory resources to be able to find a solution to a problem that requires this manipulation as one of the moves.

Here is what happens to the comparison between studying worked examples and solving problems as students become more familiar with a procedure needed to solve a problem. Initially, for reasons discussed previously, studying worked examples is beneficial compared with solving the equivalent problems, generating a worked example effect. With increased familiarity, that advantage decreases, then disappears and finally reverses, with practice at problem solving being superior to studying worked examples. That reversal is an example of the expertise reversal effect. (There are many other examples — the expertise reversal effect applies to all cognitive load theory effects including ones unrelated to inquiry learning.) With respect to inquiry learning, problem solving practice can be superior to explicit instruction rather than the reverse, but only once learners' levels of expertise in an area have increased sufficiently for them to understand the procedures being taught.

Conclusions

Inquiry learning is commonly emphasised in curriculum documents. However, a rationale for including the procedure is almost never provided. The fact that inquiry learning has inevitable cognitive consequences is routinely ignored. Curriculum writers seem to assume that learners do not come equipped with a cognitive architecture that must interact with instructional procedures.

Once we consider inquiry learning from a cognitive perspective, its deficiencies become glaringly obvious. As far as can be seen, inquiry learning neither teaches us how to inquire nor helps us acquire other knowledge deemed important in the curriculum. No inquiry learning or problem-solving strategies are ever offered. The failure to provide such strategies leads to the suspicion that there are no such strategies known to the promoters.

The lack of any theoretical justification for inquiry learning might not matter if there was empirical justification for its use. But the evidence from randomised, properly controlled trials all points in the opposite direction. The worked example effect clearly indicates the importance of explicit instruction when learners are presented with novel information. Problem solving only becomes viable as a learning procedure once learners are sufficiently expert to require practice of a specific procedure. It does not work as an introduction to a new topic as confirmed by the many studies of the expertise reversal effect.

Evidence from randomised, controlled trials is not the only evidence indicating that inquiry-based learning impedes rather than facilitates learning. The ultimate evidence against the use of inquiry learning comes from correlational studies based on international tests.[20] Studies such as these asked students to report the extent to which their teachers used inquiry-based learning in their classrooms as opposed to explicit instruction. The results indicated a negative correlation between an emphasis on inquiry learning and international test results. This tendency for test results to decrease with increased use of inquiry learning goes some way towards explaining the dramatic fall in rankings on international tests by nations emphasising inquiry-based learning.

Hopefully, the combination of a missing theoretical base and strong empirical data from both randomised, controlled tests and correlational studies will go some way towards reversing the headlong rush to embrace inquiry learning and the resultant slide to worsened outcomes.

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Analysis Paper 24 (AP24) • ISSN: 2209-3753 (Online) 2209-3745 (Print) • ISBN: 978-1-925744-90-3

Published August 2021 by the Centre for Independent Studies Limited. Views expressed are those of the authors and do not necessarily reflect the views of the Centre's staff, advisors, directors or officers.

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