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Here is an adaptation of the classic problem solving method<sup>1</sup> to computer programming. It applies to coding exercise problems in (functional) programming languages with a REPL (read-eval-print-loop). Problem solving is a messy business, asking these questions during the process may help.

#### UNDERSTANDING THE PROBLEM

No point in writing code without knowing what to do.

*What is the input? What is the output? What are the types of these data items? What is the connection between input and output?*

Think about a few example cases. Use pen and paper, draw if necessary. Introduce suitable notation. Notation on the paper can be used for names in the code later.

#### MAKING A PLAN

Decomposing the problem into smaller and simpler tasks.

If you are a beginner, **play in the REPL!** Use functions that work with the data types of the input and output. First just play freely, try many related functions, even without any obvious connection to the problem. This is for refreshing memory, and for simple problems, using an existing function might turn out to be a solution.

Trying to solve a problem in one go is a sign of lacking a plan. Making a plan is identifying the steps needed, i.e. decomposing the problems into simpler ones. *What are the steps of data transformations? Can we combine existing functions to do work? Can we specialize a function to fit the task? Do we process collections? How to process an element? Do we need to extract the required data items from the input?* If needed, by wishful thinking, come up with functions that would make solving the problems easier. *If we had a function that computes  $x$ , and another that computes  $y$ , would it be easier to solve the problem?*

If the problem is too difficult, try solving a similar, but easier problem first. *Is there a more general problem? or a more special one?*

#### CARRYING OUT THE PLAN

Write code, test code.

Test each step, each function if possible. Make the write-code-test-code cycle as short as possible. Do not do deep nested calls without checking each function. Mistake in the first step may appear later, disguised as a totally different problem. *Did we get the first step right? The second? ...What are the test cases? Can we reason about the correctness of the code?* When confused, go back to function definitions, examine their source code. Throw away code that does not work. Leftover code from dead end attempts and different half solutions turn the original problem into a harder one. *Do we use this line of the code?*

#### LOOKING BACK

Check, reflect and learn.  
Rewrite for improvement.

*Can we check the solution? Does the program do more than what is needed? Is there a way to simplify this solution? Is there a different solution? Can we use the function or its method to solve other problems?* Refactor (rewrite) for simplicity, efficiency or wider applicability.

<sup>1</sup>*How to Solve It – A New Aspect of Mathematical Method* by George Pólya, Princeton University Press, 1945.

Trying to solve a programming problem can be a daunting experience. Not knowing how to start, or not understanding why the code is ‘misbehaving’, no clue about the next step, these are intimidating and frustrating. On the other hand, programming is not magic, anyone with a bit of patience can learn it. Here are a few pieces of advice, that may (or may not) help overcoming these difficulties.

## Where do ideas come from?

From previous experience.

*Have we solved a related or similar problem before? Can we use its result? or its method?*

By result we mean that a function written for a previous problem may be usable for the current problem. Especially, if it was refactored for generality in the looking back phase. By method we mean the source code of previous solutions. Same type of algorithm might be applicable here. The solution might be recursive, or a folding.

## Practice

It is not a big secret. If we keep doing something, we get better at it. Solving more and more problems makes you a better programmer.

What is less known is that solving a problem only once is often not enough. Performing musicians do not stop practising after they could play the whole piece without mistakes for the first time. They play it again, to reinforce the memory and to improve the playing style. Same for programming. You solve a problem, for the first time, probably with the help of someone or the Internet. Then you should clear the screen and solve the problem again – this time alone. And again. Repeat this a few times, then you will see a better way to do it. Eventually, you get bored, and that is a good sign. You can move to a harder problem.

## Reflection

It is always a good idea to be conscious about the steps we make. This is not to state the obvious that we can’t write programs while sleeping. Rather, asking questions like *What did I do? Why did I do that? Is this taking me closer to the goal?* When progress has been made, *Is there a better way? Is this solution can be used for something else?*

We tend to do this naturally, but not to a large extent. It pays off to ask these questions explicitly. Maybe having a checklist of these questions handy when coding is a useful habit.

## Pen & Paper

Not to be dismissed as an old technology. One of the most accessible forms of external information representation. No need to switch between windows or scroll the page on screen. It helps to reduce the number of things we need to keep in mind at the same time.

Philosophically, it is just another type of computer. A computer can be defined as a device that stores, retrieves and transforms information. A sheet of paper can do all three. Storage: we can write on it. Retrieval: we can look at it. Transformation: the identity map.

## Beginner's mind

Most problems, and delays in problem solving are due to the false belief of knowing. “I know how this function works.” “I know what this call returns.” These statements may or may not be true. When they are false, they prevent us from checking that and we try to look for the problem somewhere else. The beginner's mindset helps. We admit that we don't know, so we can freely ask simple and basic questions.

## Variations

When the code doesn't work, we go through it step-by-step. Again and again. If the problem persists, it pays off to change something in the revision. Maybe the order of steps.

## It's OK to be confused.

Really. Abstract thinking is a defining characteristic of human beings, but in programming we take this ability to extremes, so it does not come that easily.

Professional programmers also have the feeling of being lost frequently. For example, even if someone is a master of a language, still, there is a need to work with someone else's code, and exploring the unknown is not a straight process. Being professional means that you know how to recover quickly by going back to the point where you got lost.

## Play in the REPL!

This is a repeated advice, but what does it mean exactly? Playing with what?

Playing in a sense of just trying things out, just reminding ourselves how data structures behave under certain functions.

What are the data structures mentioned in the problem? Characters and strings? Then let's just turn a bunch of characters into strings, or blow up a string into a sequence of characters.

## Learn to throw away code

For small problems, it is a good idea to restart problem solving a couple of times. We are bound to make mistakes, and it is often difficult to understand what goes wrong. Debugging takes a long time. After erasing everything, we might have a good chance of not making the same error again.

If you keep code that is not really working, then it becomes part of the problem to be solved. In software engineering, the practise of throwing code away is very much needed too. Unfortunately, it is often impossible. This happens for instance when come not so good code is in use already. This the problem of *legacy code*. You may need to make a lot of effort to code around a previous mistake, trying to neutralize it. You basically replace the original problem with a lot more difficult one.

## Wishful thinking

Problems seldom can be solved in one go. Don't expect to be able to do that. No one can. The trick is to be able to break down the problem into smaller and easier ones. The most natural method is to make wishes.

I have to go through a collection and find elements with a certain property.  
I wish I had a predicate function that can decide whether an element has that property or not.

There you go! Now you have a simpler problem, just write a predicate function.

## Know when to stop

When doing problem seems too difficult even after a long period of time, it is often a good idea to take some rest or do something else. The brain doesn't stop working, it continues subconsciously. So when you revisit the problem, you may just simply see the solution.

## Do only what is needed

Modern programming languages automate many things. For example, functional languages with `map`, `filter`, `reduce` take care of dealing with collections. You only need to create functions that deal with a single element of the collection.