The duality of complex concepts in engineering education: The example of the Laplace transform

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How many times have we not been fighting with the computer, when we needed to write an article? Sometimes our problems are not related to just technical problems or errors, but they are related to our lacking knowledge of how the computers works. Some people might suggest: "don't fight the computer, try to understand how it works, so you use it more effectively". Answers that come to mind are "I don't have enough time or initiative to become a computer programmer", or "I don't need to be a specialist on computers for the applications that I actually use".

The point here is to exemplify what we call "duality of complex concepts":

The *first aspect* there the computer is considered as a *tool* for writing an article. In this case we don't really need to know much about the computer in itself.

The *second aspect* there the computer is considered as a *complex object in itself* composed of hardware and software. Most people are oblivious of its internal structure, electronic components and programs, and how they function. This, however, does not make it impossible for us to use the computer, even though a deeper knowledge makes it possible for us to use it more efficiently and exploit more of its functionality.

Among engineering students it's sometimes possible to see this duality of complex concepts. Students have to learn and be able to handle complex concepts, using them as tools to solve problems and build the student's knowledge. However, not all students reach this goal, in the sense that they will learn how to use a complex concept to solve problems, but without thoroughly understanding the meaning of the concept.

We have made interviews with teachers regarding engineering students' problems with the Laplace transform. In our analysis we found as a common "key-point" in teachers' views that to use the Laplace transform tables to solve differential equations did not present a major difficulty for the students, but when studying the Laplace transform in itself, or trying to give it a physical interpretation it becomes a difficulty for the students.

Thus, we can see the duality of the Laplace transform, through its two aspects: The *first* is that the Laplace transform is a *powerful tool* when solving, for example, electric circuit problems. The *second* is when the Laplace transform is studied as a *subject of its own*. In this case an understanding of, for example, calculus of complex variables and linear algebra are required. The Laplace transform easily becomes complex, inaccessible and abstract, i.e. a threshold.

This is a way to show that the Laplace transform, as well as other complex concepts, can be viewed from two different perspectives, that is, it's possible to see students having trouble understanding the Laplace transform, but they are able to use it as a tool. The teachers interviewed in our study confirm this. We claim that it is important to be aware of this distinction when designing for learning and investigating 'troublesome knowledge', 'complex concepts', 'key concepts' and 'threshold concepts'.