

# ON STUDYING AND DOING SCIENCE

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***Science is an infinite regression - behind each answer lurks a question, and behind that, another.***

**- Hans Christian von Baeyer**

**All progress in both science and education depends on the questions asked. The above quote, perhaps more than any other that I can immediately recall, reflects how I feel about the way progress is made in science. Experimental observations raise questions that must be addressed theoretically. Theoretical models raise questions that must be tested experimentally. In both cases, it is necessary to extract from either the theory or the experiment results and conclusions - which are always answers to the questions asked. Without the carefully formulated questions, little would be gained from either theory or experiment. Progress in science ultimately involves an interplay between theory and experiment - all based on the questions asked of both.**

**There is a difference between *studying* science and *doing* science. The process of *doing* science is much like assembling a jigsaw puzzle but a puzzle without the boundary "edge" pieces - or even a picture to guide you, although you may be convinced that it will make sense as you assemble it. (One of the *thema* of science is that the universe is ultimately understandable.) You proceed hoping that you can obtain all the pieces, but do not know how many pieces that will be nor the size or shape of the completed puzzle. Indeed, you suspect that the puzzle may never even be completed (although small parts of it may form a coherent picture), but will continue to grow and change - and reveal new surprises and insights as it develops.**

**To do such a puzzle, you must examine each piece carefully, learning its**

shape and colors and patterns and symmetries, turning it over and seeing it from different perspectives. Then you must look to see how it connects to other pieces - whether it adds to some fragmented part of the existing picture or whether instead it seems to open new vistas. For no matter how familiar you are with any one piece, no matter how well you know and understand it, it will still make very little real sense until it is seen in the context of other pieces that surround it. Then as pieces begin fitting together, they will create a larger more understandable pattern or picture. Even as small areas of the puzzle are completed, those areas will truly be understood only when they can be seen in relation to the surrounding areas. Each part of the picture contributes to the overall understanding of the puzzle. And sometimes, when the connections are made, your perception of the importance of any one piece may dramatically change - the piece that you thought you understood well, may play some very different role in the overall picture.

When you study science, you are covering ground that others have already covered. The logical connections are already understood by others - and your study of the material involves making those connections for yourself - to form a coherent picture in your own mind. You must be willing to explore - take an idea or question and examine it, see where it came from, turn it over and look underneath it, pull it apart if necessary and examine its components. Then reassemble it and see how it fits with other ideas. It too is much like doing the jigsaw puzzle described above. The difference between studying and doing science, however, is that the picture you are trying to assemble has been done by others - and hence there is a guide picture. But just looking at the guide picture is no substitute for assembling the puzzle yourself. The discovery - in fact, the *excitement* of the discovery - is very personal. That others already understand the ideas and how they go together does not detract from the value of your own quest to understand.