Research: What is different than class work?

Let me start our discussion with a quote that has been my motto for years now. Sir Hermann Bondi started his keynote address during the inaugural dinner for the opening of the International Space Science Institute (ISSI) in Bern, Switzerland, in November 1995.

*Science is the Most Daring Spiritual Enterprise Humankind has Embarked Upon*

This quote reminds us that science is a journey with no final destination. There is a goal, and we will always reach transition points, but never a final destination. “The path is the goal”, in the same way as a Yoga Teacher, whom we had been visiting in Switzerland, put it for doing yoga. See the similarity between science and a spiritual path, like in the quote? For me this exemplifies that doing science (or research) means always something new, and the knowledge will never be completely finished. As we reach the answer to one of our questions one, two, or three new ones will undoubtedly emerge. And these won’t necessarily be questions your teacher or advisor will pose as your next homework. You will confront yourself with the questions!

Let me right away add two other very profound (in my mind anyway) points that Hermann Bondi made in his speech. He pointed out that there is no way we could ever make progress in science (research), if we are afraid of making mistakes. This means, if we hesitate to start an experiment, or hesitate to make a statement about new finding, or hesitate to right down a newly derived formula, because we think it might still be wrong, we will stop short of progress. In other words, if we perform an experiment and we find exactly what we predicted, this may be great and satisfying, but we haven’t learned anything new. We just confirmed what we already had found before. If the experiment returns “No” for an answer, we often are on to something new! There is no such thing as shame for having come up with the correct next step. The mishaps, missteps, and blunders are a natural part of the path. Along this line Hermann Bondi reminded us, the teachers and/or advisors, in a second, related, remark that we have the duty to tell our students also of our mistakes and the wrong turns that science have taken in between.

My winding evolution to the point where I am now ....

Discovery of interstellar pickup ions ...
- We had the right instrumentation (built for something else though)
- We were looking for pickup ions (different ones though)
- Next: fishing expedition for the neutral gas source!
- I could make good use of work done for a seminar talk as a student (Don’t throw your reference material away!)

This finding opened the door to a wide new research field, which is still ongoing, fruitful, and at the edge of what can be done in the solar system. It also brought me in contact with one of the potentially most daring exploration missions of the future (if the scientific community and NASA get their act together): Interstellar Probe! However, it still has quite a few technical challenges ahead.
Let us take this opportunity and break up the boring lecture part of our class by doing a related activity, in which we explore some of the issues together. I would like to point out that this is new to me, too, in two ways: 1) This is a new way of teaching, by inquiry. You should be doing the searching. I haven’t taught an inquiry course yet, I only went to some workshops about them. Well, in your research towards a Masters or PhD Thesis what better place to be than in “inquiry”. 2) I am not an expert in solar sails! I picked this topic for that reason. A) We can work on inquiry together, and I don’t have a big advantage. B) I want to promote the idea that you will have to become the instant expert in your subject, even surpassing your advisor!

Present Key Problem for Interstellar Probe

Present Solar Sail as one potential solution!
Key: Use of photon pressure to counteract the sun’s gravity
Give one hint: Photon pressure cancels gravity for a total structure weight of approximately 1 g/m².
In order not to carry along lots of propellant for controlling the course of the probe, the sail should also be used to steer the probe and to keep its path.

Activity 1
Work in 2 groups on the following:
First you may want to convince yourself that Solar Sails are a potentially good idea to pursue, even if there are problems ahead.
What are good arguments for a Solar Sailing technique for interplanetary spacecraft?

What are potential pitfalls with the method?

Which scientific and/or technical problems need to be solved to develop an effective Solar Sail?

Given the responses above, compile questions that you want to get answered to make headway.
Now that we have compiled a few potential questions, let us steer towards tackling a first problem. This reminds me of my start as a graduate student in Bochum, Germany (although there wasn’t such a distinction between undergrad. and grad. student in Germany back then; you just started to do research as part of your studies towards you Diplom, the first degree).

Tell story of starting the Diploma Thesis; expectation of being expert in one of the diagnostic techniques (Langmuir Probes) and in your own field.

Resources: advisor; immediate advisor in small group; your peers

a) Advisor; immediate advisor in small group;
b) Your peers
c) Of course there are papers on the subject, there is the www these days. It is always good to get a good foundation in a specific subject, but don’t try to be complete! A good Review article that your advisor may give you or some key articles from your new research group, just to start you off. Now you are on a hunt for other material that explains to you what you do not yet understand. We’ll talk about search tools later! But, don’t wait until you think you understood everything done before, before you start with your new work!! You never will, and you lose out on the fun!!

What if you bang your head against questions that nobody in the group, not even your advisor, seems to have an answer or even a good lead towards the next step for?

d) There are other faculty members in the Department and in the College! Your advisor may bring them in. Or you may seek them out!!
e) Don’t be shy to ask for help to get in contact with researchers in your field at other institutions! (I got to go on travel to Munich twice during my Diploma Thesis work.)

Be aware, to take a next step means stepping into the unknown! You will have to take leaps at times. Let your intuition guide you. There is nothing wrong with that! However, then it is your task to test your intuition against scientific models and prior observations. This is where your solid foundation in physics comes in. But, it will never be complete. So, at times you will have to teach yourself a new method/model or so. Or you may approach someone to teach you.

Now let’s try this out with one example of a question/problem that we uncovered for our Solar Sail. (Unless we bring up a very good new problem) Let’s tackle how to control the orientation of the Solar Sail.

Explain the Problem ......

Activity 2

Control the direction of the force exerted by the Solar Sail.

Work in groups of 2 or 3.

First convince yourself that this is a potential problem and that it is a good idea to do this all in one solution.
Compile arguments for the use of the Sail as control element.

Figure out what happens, when the direction deviates somewhat from the direction intended.

Compile ideas how to use the Sail to control the direction of the force on the probe.

Let me bring up one issue that could potentially be very frustrating! The question that your advisor assigns and/or the questions that you come up with as your next task may not have the intended solution/answer. After all this is research of something that nobody has done before. In such a case, your advisor, your peers, other colleagues in the field may not be aware that there is no solution in the direction they expected. First, you need to absolutely convince yourself that you exhausted every possibility. Secondly, you will have to compile arguments to convince others.

Describe what happened with my Diploma Thesis.