Student Evaluation Component

A suggested evaluation component could be developed working closely with the professors. In the future we could possibly integrate this into the software. But each instructor would develop their own evaluation by integrating the system into their teaching. A typical evaluation outline could include the following:
The students would write a report on:

1. **Method** used to perform the flow visualization tests.
2. **Analysis** of quantitative data (Particle Image Velocimetry results such as velocity, vorticity, etc)
3. **Discussion** on the flow observations such as flow separation, mixing, laminar/turbulent flow, Bernoulli principle, Continuity and other flow principles.
4. **Accuracy** of the procedure, the results and the final conclusions.
    a. Change in the variables: State how accurately you measured the results. The accuracy normally depends upon the type of equipment used, and how easy it was to take the measurements. Some things are difficult to measure accurately when they are changing quickly – for example, flow at higher speeds. The accuracy may be different over the range of results taken – for example, higher flow rates versus low flow rates. Explain all this in as much detail as possible. If you have done this then explain how the accuracy of each measurement could be improved.
    b. Anomalous results: human error: One or two results may be wrong because you misread them or wrote them down incorrectly. These should have already been clearly identified in your results and should not have been used in the analysis. If you have already written about this in the analysis then there is no need to repeat yourself.
    c. Anomalous results: equipment error: The equipment may have produced a few faulty readings – for example, the seeding density in the flow did not produce the ideal conditions for the CCD camera. Again, these should have been eliminated before the results were analyzed. If results have been corrected due to faults in equipment then this will already have been explained in detail during the analysis.
    d. Anomalous results: genuine scientific anomaly: An anomaly may be a feature of the results that was unexpected and does not match your scientific model, or prediction. Anomalies may occur at specific places or they may just be a slight deviation away from the expected trend. For example, a slight curve to the graph when theory says it should be a straight line. Some anomalies may occur on a random basis and be difficult to reproduce experimentally. This is more likely to occur when there are many variables, some of which are difficult to control. Try to explain the scientific causes behind the anomalies.
    e. Inaccurate results are not anomalous: Poor results with a low accuracy will not give a graph with a smooth trend. Some points may not be close to the line of best fit. These results are not anomalous, just inaccurate. Do not make the mistake of identifying results as anomalous just because the graph isn't perfectly smooth.
    f. No anomalous results: If you have done a simple experiment well then the chances are there won't be any anomalous results. State that there aren't any anomalous results, giving your reasons why.
5. **Reliability** of the procedure, results and conclusion.
    a. An investigation is reliable if anyone can repeat your investigation, using similar equipment and the same method, and come to the same conclusions you have reached. You may be certain of your conclusions for a simple experiment, but with something like fieldwork there may be a variety of possible conclusions.

  b. Your conclusions are also only valid over the range of values you have investigated. You can only speculate as to what might happen outside this range of values - for example, higher viscosity fluids, or much higher flow rates than the equipment can produce.
  c. In general, the more accurate the results, the more reliable the overall conclusion will be. Consider the accuracy of all your measurements and decide which part limits the overall accuracy. There is often one part which is a lot less accurate than the others. This usually decides the overall accuracy and reliability of the experiment.
  d. You must also think carefully about all the control variables. Were there any that were difficult to control, or impossible to measure, which may have affected the results?

6. **Improvements** that can be made to give more accurate and reliable conclusions.
  a. Suitability of the procedure: Go through each bit of the procedure and explain how and why it worked well, or didn't work so well. Explain how you would change the procedure if you were to repeat the investigation.
  b. More repeats: If you were short of time then you may have had to cut back on the number of repeats you could fit in. If this is the case then taking more repeats would improve the reliability of the evidence. Be specific in stating exactly what needs to be repeated, how many times, and why it needs to be repeated. Just saying "I needed to repeat the experiment more times" will gain you no marks at all.
  c. More in-between results: It is much more common to find that there is an area of your graph that could be improved by taking more in-between values. This is particularly the case with curved lines, and where an equation has to be used to calculate the plotted values. Often the points are squashed together at one end of the graph and spread out at the other. Simply look at the graph and work out roughly what extra values you would need to test, and the corresponding values of the independent variable.
  d. Bigger range: A bigger range may enable you to extend the scope of the conclusion. Work out what additional ranges of values, bigger or smaller, you could test. You may not have been able to investigate these because of a lack of time, lack of materials, or equipment of the right size not being available.
  e. Changes to control variables: Altering the value of one or more of the control variables may lead to an increase in the reliability of the results. Discuss how this could be achieved. Better monitoring and control of variables could also lead to an increase in the reliability of conclusions.
  f. More equipment: Just about any experiment could be improved with "more and better equipment". Therefore you only gain marks for specifying particular pieces of equipment and explaining how and why they would improve the experiment.

7. **Additional** experiments that could be performed to improve the conclusion or extend the understanding of the observed flow theory.
  a. Other variables: Suggesting another variable – for example, temperature of the fluid - to investigate sounds a good idea but you must be careful. There must be some sort of clear link between the other variable and the one you have investigated. This could be that the same scientific theory used to explain your investigation can also be applied to the other variable. If the theory works for both, then that improves the reliability of the conclusions to your investigation. Remember that you are trying to extend the investigation, not investigate something that is completely different.
  b. Alternative experiments: You may be able to make use of the research work carried out during the planning stages. Often you will find that there are other ways of carrying out your experiment using different methods or different equipment. This often involves equipment that is not available to use in a lab either because it is too complicated or too

expensive. These alternative experiments provide an excellent extension to the investigation since they provide a different or better way to check your conclusions.

c. Textbooks containing just laboratory experiments are often a good source of ideas. You do not need to understand the theory of the experiments so much as the principle behind how they work. Where possible include a diagram of the experimental setup.

d. Failing this, just use your imagination to invent a much better experiment! Often you can use computer based logging or monitoring equipment in your designs. These have many different types of sensors and can be used to record events which happen very quickly or over long time intervals.