AC 2007-830: LESSONS LEARNED IN ADOPTING A CFD PACKAGE

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Lessons Learned in Adopting a CFD Package

Abstract

Computational Fluid Dynamics (CFD) used to be a luxury reserved for elective undergraduate or graduate engineering courses. Now it is being rapidly adopted in introductory Fluid Mechanics courses. This, in large part, became possible with the introduction of FlowLab, which is specifically designed for this purpose. The software is offered with several Fluid Mechanics textbooks and is free for the duration of the course. It comes with a selection of modules addressing both internal and external flows. It is designed to simplify the instructor's work and to accelerate student learning by streamlining such issues as geometry, meshing, application of boundary conditions, and data postprocessing. However, this design has its drawbacks, allowing the instructor only limited capabilities in adopting the software.

The experience of introducing FlowLab into the Fluid Mechanics course at Grand Valley State University (GVSU) was mixed. The course was offered with an integrated laboratory. Complexities arose from the need to introduce the Fluid Mechanics fundamentals before any productive work in FlowLab could be performed, leaving limited time for thorough integration. After a few introductory demonstrations and tutorials, students used FlowLab to simulate the experimental results from laboratories on the converging-diverging channel, flow over a cylinder, and flow over an airfoil. The results were mixed, ranging from an excellent agreement in the case of the airfoil to questionable in the case of the flow over a cylinder. Nevertheless, in all cases FlowLab was an excellent tool in visualizing the flow.

Adoption of the software created more work for students, which was reflected in their responses. Overall, students' involvement ranged from low to very excited. Some students asked for more features to solve real-world problems.

A number of high quality publications have recently appeared on the topic, discussing the implementation and integration of the package into existing courses and the redesign of teaching philosophy. This paper continues the discussion, confirming that further improvements are warranted on the instruction side as well as on the part of the software developers.

Introduction

Computational Fluid Dynamics (CFD) is playing an increasing role in engineering. Both the advances in hardware and numerical methods have greatly contributed to the broad acceptance of CFD in the industry. Academics, while teaching the foundations of engineering, mold the curriculum to embrace the modern engineering tools. Over the past several years, a new CFD software, FlowLab, has been introduced to the wide academic community through the extensive efforts and commitment of Fluent Inc. and several core institutions. Previously a luxury reserved for elective undergraduate or graduate courses, FlowLab now significantly simplifies the integration of CFD topics into the undergraduate Fluid Mechanics and Heat and Mass Transfer courses.

The inclusion of CFD into the curriculum takes place via several routes. Purely CFD-dedicated courses rely on the introduction of numerical methods in fluid dynamics and incorporate commercial packages like Fluent[1, 2], CFX[3] and Star-CD, to name a few, where Aung[3] provides a thorough review of literature on the adoption of commercial codes. Pines[4] discusses the adoption of full version of Fluent in an undergraduate laboratory supplementing a few experiments. However, students are provided with meshed models of experiments essentially bringing this approach to the FlowLab model discussed below.

In introducing CFD topics in undergraduate Fluid Mechanics courses, some instructors have taken an approach of custom codes or virtual reality laboratory[5, 6], where both sources review prior efforts in the field. However, virtual reality is yet to demonstrate its advantages in substituting the true hands-on experience of a graduated bucket and a stop watch, demonstrating the flow detail, and preparing for commercial software in the workplace.

A recent newcomer, FlowLab, is gaining popularity, wide acceptance, and publication activity. FlowLab is essentially based on Fluent, where students are supplied with case-particular modules. Each module has the geometry drawn, and the mesh and some advanced solution options easily selected. The postprocessing is also significantly simplified. Students enter types of flow, fluid properties, boundary conditions and make some other choices as appropriate in each case. Some modules allow changes in physical geometry and thus add more variation to the problem. As a result, a relatively flexible modeling environment reminiscent of a commercial software is created. Fluent software and Fluent staff support are required for the creation of a module; without these tools, the instructors are only left with what is already available, which is not always a perfect match to their individual needs. However, the benefits are overwhelming. The objectives set by the software developers[7] to create software which will provide the benefits of a commercial package are:

- flow visualization,
- insight into problems and what-if analysis,
- reinforcing learning concepts,
- providing CFD experience, etc.

At the same time, the software should be:

- affordable (and even free for the duration of the course with some textbooks as in case of this engineering program[8]),
- available with a library of free examples addressing classical and real-world problems,
- quick to learn by students,
- relatively easy to implement into undergraduate courses,
- adoptable to a variety of course objectives.

By far, the most comprehensive account of FlowLab adoption in the laboratory environment spanning several institutions is given by Stern et al.[9, 10] The papers specifically address the integration of FlowLab in an experimental environment. Student comments in Stern et al.'s publication are found to be consistent with those presented in this article. Jokar[11], Barber[12], Huebsch[13] and this paper discuss FlowLab in the framework of experimental fluid dynamics. Cimbala et al.[14], on the other hand, provide a thorough description of integrating FlowLab into a textbook with both fluid mechanics and CFD objectives defined for each of the thirty-six problems discussed.

Being a relatively novel software, FlowLab has its strengths and limitations. This paper shares the lessons learned by students and the author in adopting FlowLab for the first time. It is believed that this paper will be a valuable source of information for those who have worked or are considering working with FlowLab in the classroom, as well as for the software developers.

Course Description

The engineering program at GVSU integrates a three-semester co-op program. The co-op program starts after the sophomore year and runs by alternating co-op and regular semesters. Two of the regular semesters are taught during summer sessions, which last for thirteen weeks from May to August instead of the traditional fourteen weeks. The lecture time is increased to compensate for the shorter semester. However, the laboratory time is still three hours a week. Fluid Mechanics is offered during the summer with an enrollment of about 35-40 students a year. FlowLab was introduced in the laboratory on top of the regular lab assignments. Both the students' and instructor's work load went up as compared to previous years. Additional tasks required of the instructor were license arrangements, practicing with the software, in-class demonstrations, supplementing lab handouts, and grading assignments. Altogether the use of FlowLab adds about 2-3 hours of work per week during the first year.

The course is largely structured by two course projects. Hydrostatics, buoyancy, Bernoulli's equation theory, and control volume analysis are followed by similitude analysis. The latter becomes the basis of the first project, where students design and build model sail boats. Hull tests on the models are performed closer to the end of the semester, and predictions are made for a full-size boat. Similitude analysis is introduced at the middle of the semester and is followed by external-flow topics such as lift and drag. The second shorter project, related to a trailer-truck wind resistance, is assigned at that time for a two-week period. For a brief time, both projects run parallel to each other, as well as to weekly homework and laboratory reports. The course ends with the topics of turbomachinery and compressible flow.

The FlowLab version provided to GVSU contained the following modules:

- Flow over a Clark Y Airfoil,
- Flow over a Cylinder,
- Flow through an Expansion,
- Developing Flow in a Pipe,
- Developed Flow in a Pipe,
- Flow over a Plate,
- Flow through an Orifice,
- Several Modules with Heat Transfer Applications.

There have been numerous modules developed for other textbooks utilizing the software, but only those listed above were available with the textbook[8].

The FlowLab tasks completed throughout the semester were two in-lab demonstrations by the instructor, an introduction problem in the tutorial, a converging-diverging nozzle, flow over a cylinder, flow over an airfoil, and developing flow in a pipe.

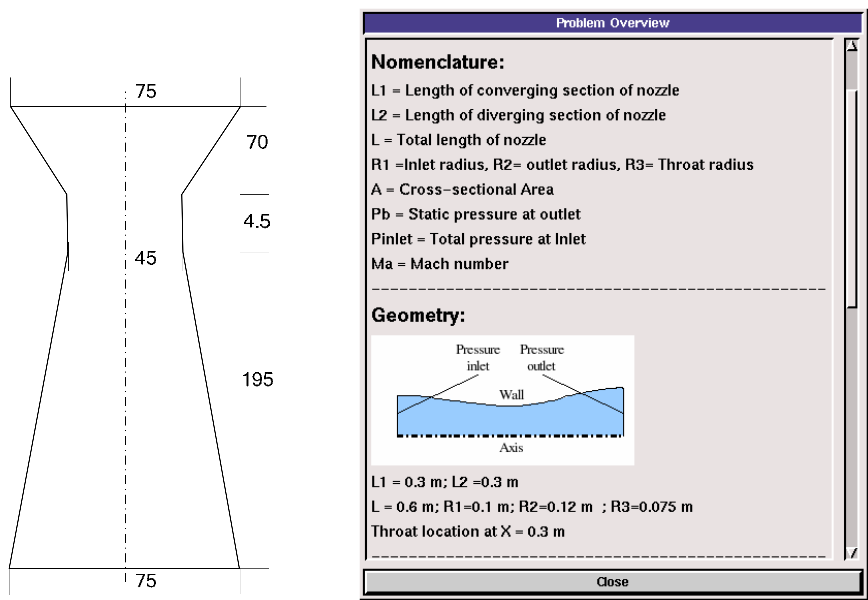
Introductory Assignment

FlowLab was first introduced on the fourth week with an in-lab demonstration of the software. The solution steps in the FlowLab modules and as much as possible of the CFD philosophy were explained, and an example problem was solved. During the demonstrations, the computer display resolution was lowered to match that of the on-screen data projector. This caused some difficulty when the Contour or Velocity edit menus were displayed in the postprocessing mode. The Edit pop-up window would show only partially, cutting off the screen some important function buttons, such as Accept or OK. Activating the Tab key was not helpful. This would essentially terminate (or indefinitely extend) the demonstration when it neared its end.

The Developing Flow in a Pipe tutorial was assigned as a part of a laboratory homework. The tutorial is standard and available with the textbook—Appendix J—which was downloadable from the publisher's website only (the exact reference is omitted as it requires user login on the textbook website[15]). Students were assigned to complete the tutorial and print out deliverables, engaging in postprocessing techniques. An ongoing challenge students faced at the end of their assignments was how to print out a black-background rendering of the results so it would change to white background. FlowLab has made it almost a direct action in the File menu—Set Background Color. Yet many students continued to struggle with this for quite some time.

Converging-Diverging Channel

The implementation of FlowLab in a laboratory had a dual advantage. One was the extra time afforded by the laboratory setting for FlowLab demonstrations, and the other was the ability to directly compare the experimental and computational results. The converging-diverging theory nozzle laboratory verifies Bernoulli's equation theory. The experimental apparatus is based on a TecQuipment AirFlow Bench AF10 unit equipped with the Bernoulli Theorem nozzle AF11 shown in Fig. 1. The nozzle has a 4.5 degree half-angle and uniform width of 50 mm.



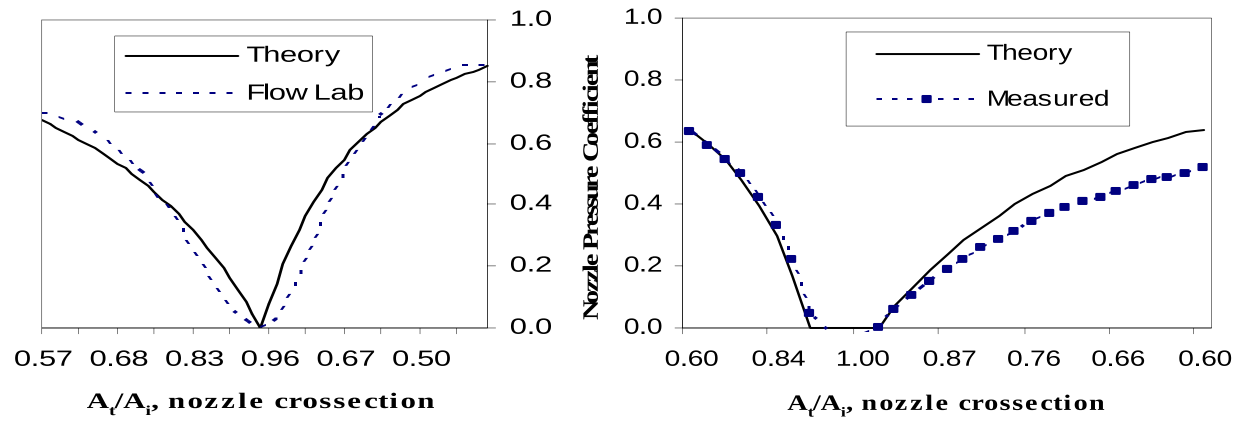
(a) (b)

Figure 1. (a) the geometry of the experimental converging-diverging nozzle (dimensions are in mm) and (b) the geometry of the axisymmetric nozzle in FlowLab.

In this experiment, the Pitot tube is traversed along the centerline of the nozzle measuring the dynamic pressure. The application of Bernoulli's theorem for this problem is given by the nozzle pressure coefficient Eq. (1):

$$\left.\frac{(P_i - P_\infty)-(P_t - P_\infty)}{(P_t - P_\infty)}\right)_{Meas-t} = 1-\left(\frac{V_i}{V_t}\right)^2\Bigg)_{FlowLab} = 1-\left(\frac{A_t}{A_i}\right)^2\Bigg)_{Theory} \tag{1}$$

where P, V and A are pressure, velocity, and cross-sectional area respectively. Subscripts i, t and ¶ are indices of location along the axis, throat, and far-field respectively. The dynamic pressure is plotted against the cross-sectional area; both are non-dimensionalized with their respective values at the throat as given in the equation above.



(a) (b)

Figure 2. Nozzle pressure coefficient Eq. (1) as function of the location along a converging-diverging nozzle (a) CFD results for Fig. 1(b) geometry and (b) experimental results for Fig. 1(a) geometry.

The results in this laboratory show good agreement with the theory in the converging section of the nozzle. The diverging portion demonstrates that the results deviate from the predictions due to secondary-flow effects.

An attempt was made to use non-dimensional theory to compare to the results from somewhat dissimilar geometry available in the module Axisymmetric Nozzle: Internal Flow through a 2D Converging-Diverging Nozzle.[16] The geometry and dimensions are shown in Fig. 1(b). However, the exact geometry of the nozzle is not known. In addition, while displaying in the results the cross-sectional area of the nozzle, the saved-to-a-file results do not contain this area, only the location along the nozzle. Students were provided with Fig. 1(b) and the data saved from the simulation performed by the instructor. The exact geometry of the axisymmetric nozzle was not known, and students were offered a linear approximation between the values provided in Fig. 1(b). The results based on the velocity data and the cross-sectional areas are shown in Fig. 2(a). While a perfect match was not expected due to the linear approximation of the cross-sectional area, it is apparent that the theory and the CFD data are in good agreement and there is no secondary flow or other losses developed in the nozzle, unlike the observations in the actual experiment, see Fig. 2(b).

This experience shows that (1) the nozzle geometry cannot be varied; (2) the cross-sectional area cannot be extracted from the FlowLab saved data though it is displayed in results; (3) secondary-flow effects are not generated in this geometry. A better match for this problem would perhaps be the use of the Conical Diffuser module discussed by Cimbala et al.,[14] which is not currently available with the course textbook. This module allows varying the angle of the diffuser, thus placing it in regimes with the secondary flow generation suspected to be present in the experimental nozzle.

Flow over a Cylinder

As the tutorial and Converging-Diverging Nozzle assignments were submitted and evaluated, the time came for the Flow over a Cylinder laboratory, which has a corresponding FlowLab module. The experiment was performed in the Aerolab Educational wind tunnel with a 12”x12” test section. It utilized the four-inch Aerolab cylinder with twenty-four circumferentially mounted pressure taps. The measurements were made at room conditions and the wind tunnel operating at 29 m/s. The results for the pressure coefficient distribution around half of the cylinder are shown in Fig. 3.

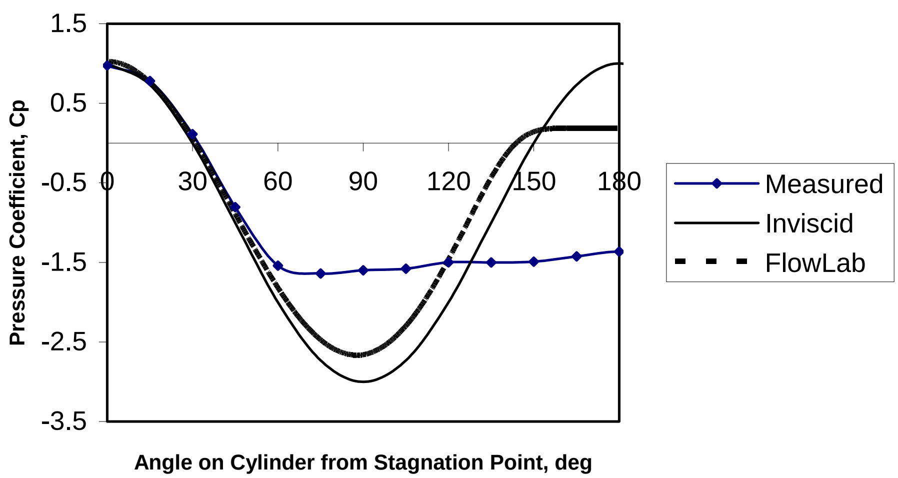


Figure 3. Pressure coefficient distribution on cylinder surface for three cases: measured, CFD and inviscid theoretical solution.

Figure 3 is similar to that reported in Stern et al. [9]. In both cases, the pressure coefficient distribution in the CFD simulation was following much closer to the inviscid solution, so that the resulting drag coefficient was much smaller than the experimentally observed value of Cd=1.27 at high Re numbers. The flow regime in the simulation was set to Turbulent with the Standard Wall Function; the rest of the settings are given in Table 2. Students were provided with the settings for the simulation, except that they were responsible to enter properties matching those in the experiment. That effectively matched the Re number, too. The need for providing the settings to students arose from the complexity of the problem and their limited CFD experience. There was a second demonstration in the laboratory that reviewed students’ previous experiences with FlowLab and introduced the particularities of the Flow over a Cylinder module. The demonstration also included instructions on how to observe the animation of vortex generation and shedding in the postprocessing mode.

The largest of the residuals in the simulation was the continuity coefficient, which, after initially large values, consistently stayed below $1x10^{-5}$. The other residuals were of smaller magnitude.

Table 1. Settings and some results of FlowLab simulation for Flow over a Cylinder.

Property	Value
Re#	186390
Number of timesteps	1000
Time Step	0.005 s
Total Time	5 s
Iterations per time step	20
Convergence limit	$1x10^{-4}$ s
Running time, CPU 1600 MHz	> 1 hr
Cell count	23950
CD	0.094

The discrepancy in the values obtained in the simulations was a significant detriment to the students' acceptance of the software. Yet, it was a valuable lesson in CFD, where convergence of the solution does not necessary mean that the results are physically correct and the investigator should pay extra attention to verification. Another lesson was that, despite powerful computers, CFD is still very taxing on the hardware and the user's time.

Flow over an Airfoil

The experiment measures the lift generated by the Aerolab Clark Y-14 airfoil with a chord of 3.5 and eighteen pressure taps. The airfoil is installed in the Aerolab wind tunnel described above. An angle of attack is set, and the pressure distribution around the airfoil is measured. Figure 4 represents a typical pressure coefficient distribution for angles of attack of 5 and 10 degrees at 37 m/s.

The corresponding FlowLab calculations were carried out by students using the Flow over a Clark Y Airfoil module. This module comes with the preset chord of 0.4 m, which is about 5 times larger than the one in the experiment. In addition, the far field conditions are set for a high altitude flight, and the speed is specified by Mach number rather than a direct value. All that presented an excellent opportunity for students to exercise their similitude analysis skills. All together, they needed to match the Reynolds number in the experiment. About two thirds of the students succeeded in the task; the other third did not change the far field values to those observed in the experiment and only varied the Mach number values. Matching the Reynolds number of 222,700 resulted in an erroneous Mach number of 2.5 instead of the correct 0.0234. Not only was the value plain wrong, but it also was placing the flow in a compressible, supersonic regime of flow. The pressure distribution plot around the airfoil in this incorrect case demonstrated the shock waves forming on the leading edge. This, in turn, provided for some valuable discussions of FlowLab capabilities to model various regimes, investigator's responsibilities, and the compressible flow which was studied in lecture at the time of the review.

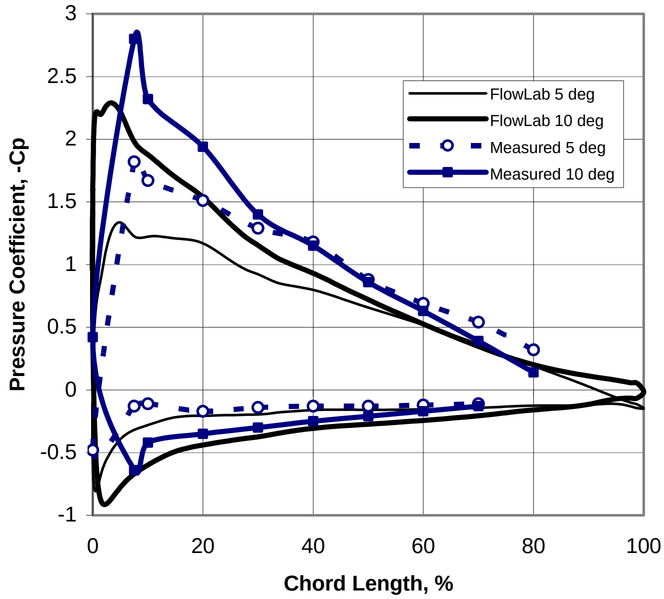


Figure 4. Pressure coefficient along an airfoil in experiment and CFD.

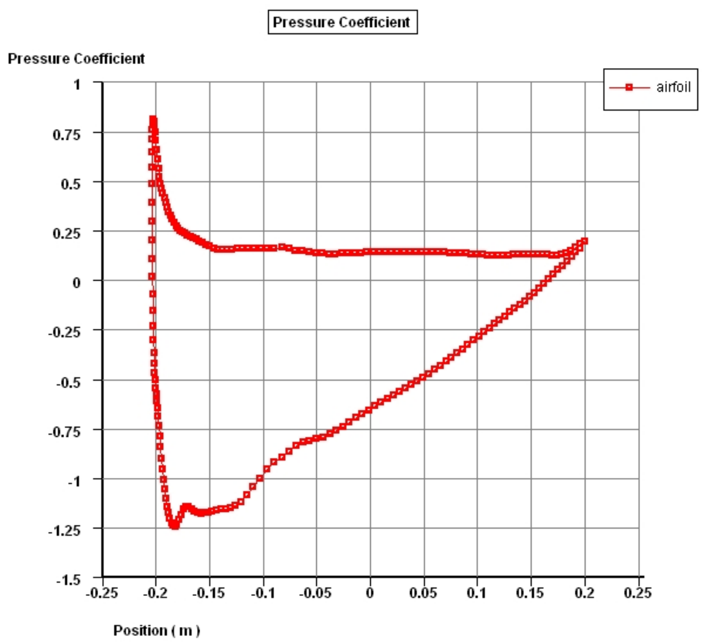


Figure 5. Native FlowLab plot of pressure coefficient along an airfoil at 5 degree angle of attack.

Students were required not only to obtain the lift coefficient but also to superimpose the pressure distribution coefficient, see Fig. 4. There, once again, proved to be a challenge of matching

FlowLab to the particular needs of the instruction. Figure 5 demonstrates the native FlowLab plot of pressure distribution for the 5 degree angle of attack. Traditionally, the pressure coefficient for an airfoil is plotted so that the top airfoil surface coefficients appear on the top, which requires multiplication by negative one. Figure 5 represents this in a non-traditional way that requires additional manipulation to adapt to the experimental graph. The true chord position also has to be manipulated to be presented in the percentage of the chord format.

Overall, the results obtained in the experiments and in FlowLab simulations correlated well with the published values,[17] as shown in Table 2. The simulated results had an even better match to the published values than the experimental.

Table 2. Lift coefficient for Clark Y airfoil.

Angle of Attack	Measured	FlowLab	Published
5°	0.89	0.8316	0.83
10°	1.13	1.1866	1.18

Developing Flow in a Pipe

The last FlowLab assignment was rather straightforward and did not present any particular issues. Because one of the laboratories fell on July 4, the short summer lab schedule became even shorter. The traditional laboratory where students investigate the Flow in Pipes topics was substituted by numerical simulations of laminar and turbulent flows in pipes using the Developing Flow in a Pipe module again. The main objective of the assignment was to verify the empirical entrance lengths for the laminar and turbulent regimes, which was accomplished rather well by students. Some other deliverables were also required to strengthen postprocessing techniques and were satisfactory as well.

An ability to substitute an experiment with a CFD simulation demonstrated one of the major strengths CFD possesses—to produce reliable results in a short time.

Discussion

FlowLab, a CFD software, was adopted to the Fluid Mechanics course at GVSU. While some challenges existed and the workload increased, the instructor and a majority of the students judged the overall experience as positive. The software is designed in such a way that the instructor’s time spent in adopting the software is reduced as compared to commercial versions of CFD packages; the students’ learning of the software is also less steep.

Early preparation was one of the key elements in successfully adopting FlowLab. The instructor acquired an evaluation license from Fluent a few months prior to the course’s start date. Several key modules were evaluated, and experience with the software was gained. The instructor had had prior commercial CFD experience and most of the software functions were straightforward with a few exceptions that were easily resolved through reading the Help files. The twenty-five seat, free course software was obtained three weeks before the start of the semester. However, the license installation was not smooth. Using e-mail help to resolve the license issues as required by Fluent did not provide any results, as there was no response for days. Eventually, the

Fluent staff from the educational department resolved the issue over the phone. Two weeks into the semester FlowLab was fully set for student use (and instructor's peace of mind). Actual use of FlowLab started on the fourth week, once students had the necessary background to begin using the software.

Overall the four FlowLab modules described above were adopted in the course. At the end of the semester, students were anonymously surveyed about their response to the software. The survey consisted of six questions:

1. Was working with FlowLab helpful in understanding the associated laboratory?
2. Was working with FlowLab helpful in gaining insight into problems solved?
3. What other benefits do you see in working with a CFD package like FlowLab?
4. FlowLab is an educational software, are you interested in learning how to use a commercial CFD software and why? Rate your interest from A to D.
5. What were frustrating experiences with FlowLab?
6. Your recommendations for further adopting of FlowLab. Or any other comments.

Selected student answers to the questions and the numerical data to questions 1, 2 and 4 are summarized in the Appendix. In general, student comments resemble those found in publications on the topic. Students recognize the value of CFD for the visualization of flow details or its helpfulness "to see the theory in visual forms." Many students consistently identify the benefits of CFD: "It can produce much more data and details than the experiment can"; "CFD would allow you to gain insight into complex problems that would not be possible with analytical techniques." However, some comments indicate frustration: "It seemed that most of my work within the software was guessing or hit and miss"; "It seemed like the instructions were followed just to complete the assignment." Drawing on comments that ask for "more guidance in using the software or have manuals available," it is believed that as instruction techniques, materials, and assignments are honed, students' acceptance of the software would improve. Students also suggested using the software for prelabs rather than after the experiments.

Students had a few suggestions for software developers about modernizing the graphical interface, as they noted the lack of "labels on many of the buttons (when you scroll over a button, the name should come up). Complicated, unnecessary commands for view changes." Students occasionally complained about FlowLab crashes, which were not experienced by the instructor. This survey revealed a problem particular to the site. Students working on the network had limited space allocated to personal accounts. FlowLab generates relatively large files while it is running. In addition, students stored their work from another finite element analysis software, which also generated generous file sizes. As one of the options to resolving this problem "the student version of FlowLab could be purchased for use at home or on a laptop." Individual laptop usage on campus would have been technically possible, but such practice was discouraged by Fluent.

The analysis of student responses also reveals that they were influenced by the particularities of the engineering program at GVSU. The engineering program, as mentioned previously, intensively integrates a co-op program. By the time students start Fluid Mechanics, they have had two semesters of co-op. Some students participate in the course and its assignments only as required, "since my work experience has been primarily with production or mechanical components and/or assemblies" (a recurrent comment in the survey), and "because I, like most of the students, will not need to perform complex fluid analysis on the job."

Another particularity lies in the extensive usage of ANSYS. Students suggest that directly "learning how to use commercial CFD might be more useful," based on their experience with ANSYS. However, these few students forget that they have had several courses in the solid mechanics sequence before learning ANSYS, and a large part of the laboratory time is dedicated to practicing the software. This is different from FlowLab, which enables great results from the start with minimum lead time in the course. In addition, a multi-seat license for a commercial CFD package to solve a few problems in one or two undergraduate courses might seem spendthrift.

The survey also shows that students did recognize and achieve the main goals set forth for integration of FlowLab into the course: "the practical experience gained through using FlowLab in this class provides a solid foundation for understanding other software packages," and "it would be very intriguing to use the several packages that were available to see the airflow around complex bodies and shapes."

Conclusions

FlowLab is a well designed CFD software meeting its objectives, which greatly contributed to its successful integration into the Fluid Mechanics course and laboratory at GVSU. Several FlowLab modules were adopted in parallel with their respective laboratories, further reinforcing the theoretical and experimental concepts.

Students responded positively to their experiences with the software, and their comments were consistent with those found in literature. While generally the software is user friendly, the instruction side will benefit from more customized tutorials and more time for training in the beginning to make students more comfortable with the selection of settings. All of the FlowLab work was in addition to the usual course load, so revisions of the laboratory curriculum to create a stand-alone FlowLab session will enhance the student's proficiency with the software.

Creating new modules requires full Fluent version and Fluent staff support. Because curricula differ, a greater variety of or more flexible modules will aid wider and easier adoption of FlowLab. Updating the user interface and streamlining some options will address students' concerns about their comfort with the software. Furthermore, providing benchmarking examples in the module tutorials will boost student confidence and avoid the uncertainty experienced in the Flow over a Cylinder module.

An early start is essential for the initial adoption of FlowLab. Making student licenses available for a nominal fee will allow for more flexible time management, so that time consuming problems can be assigned without overwhelming computer laboratories.

Acknowledgments

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Appendix

Table A1. Sample student responses to a survey on FlowLab experiences.

<table>
<tr><td>Question 1:</td><td>Yes</td><td>Middle</td><td>No</td></tr>
<tr><td>Was working with FlowLab helpful in understanding the associated laboratory?</td><td>12</td><td>9</td><td>10</td></tr>
<tr><td colspan="4">Yes. For example, the contour plots were excellent tools for visualizing the nature of flow around, or through, an object.

Overall, it was helpful. It was a nice way to verify theoretical calculations and compare to experimental data.

It did help to see pictures of streamlines and contours, but I don't think FlowLab really helped me understand the labs any better than a good explanation from the instructor.

Flowlab assignments did not help much to understand the labs. It seemed like the instructions were followed just to complete the assignment, not so much to understand the lab question at hand.

Not really... it seemed that most of my work within the software was guessing or hit and miss....</td></tr>
<tr><td>Question 2:</td><td>Yes</td><td>Middle</td><td>No</td></tr>
<tr><td>Was working with FlowLab helpful in gaining insight into problems solved?</td><td>17</td><td>4</td><td>8</td></tr>
<tr><td colspan="4">Yes because it can produce much more data and details than the experiment can.

Flowlab was helpful in gaining insight. It was helpful to see the theory in visual forms (with the velocity and pressure contours).

Sometimes and other times it was very frustrating and didn’t help at all.

A few topics here and there could be learned from FlowLab's "Problem Description" but the rest of software didn't seem to help me understand problems... at least not to the extent as the laboratory exercises....</td></tr>
<tr><td>Question 3:</td><td>Yes</td><td>Middle</td><td>No</td></tr>
<tr><td>What other benefits do you see in working with a CFD package like FlowLab?</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td colspan="4">CFD can help solve complicated problems or problems that we don't have the equipment to do in the lab.

It may speed the design process up. It was nice to be able to change the flow speeds and re-solve the solution.

I think that Flowlab is a waste of time and we should be learning how to use real software used in industry. It is similar to using a CAD program made for high school students versus Pro/E.</td></tr>
</table>

Although FlowLab may not be the specific software used by a prospective employer, the practical experience gained through using FlowLab in this class provides a solid foundation for understanding other software packages. CFD simulations seem to come close to theory in the simple experiments we did. So, if theory is correct then CFD would allow you to gain insight into complex problems that would not be possible with analytical techniques. Only in that learning a new software application is always beneficial.			
Question 4:	Yes	Middle	No
FlowLab is an educational software, are you interested in learning how to use a commercial CFD software and why? Rate your interest from A to D.	11	7	13
I am interested in learning how to use commercial CFD software because I think it could be a valuable skill in some industries. I would rate my interest as a B. No, because I don't really see any practical use for it. Yes, as mentioned above, learning how to use FlowLab is worthless because I will never use it again, but learning how to use commercial CFD might be more useful because I might use it again sometime. If A means high interest, then interest would be an A. Aerodynamic modeling of airplanes and cars would require a commercial CFD package and it would be very intriguing to use the several packages that were available to see the airflow around complex bodies and shapes. It would also be beneficial in understanding how air flows through ducts, how water behaves in large pipe circuits, or airflow mixture in engines. My current interest is about a C since my work experience has been primarily with production or mechanical components and/or assemblies. However, if I was tasked with upgrading the plant wide coolant system to a more state-of-the-art design, then my interest would be an A. I would not be interested in using commercial CFD software because I, like most of the students, will not need to perform complex fluid analysis on the job. FlowLab was good enough to investigate most simple problems we would encounter, and more complex problems could be estimated using FlowLab or simple educational software. I would give my interest a C- rating on a scale from A to D			
Question 5:	Yes	Middle	No
What were frustrating experiences with FlowLab?	NA	NA	NA
Some frustrating experiences with FlowLab were 1.) not always knowing what constants to change in the setup, 2.) trying to figure out exactly what plot setup produced the required plots. No labels on many of the buttons (when you scroll over a button, the name should come up. Complicated, unnecessary commands for view changes. Certain wording in assignments was unclear (or overall confusing). Caveats of the program were difficult and aggravating to get past. Post processing setup is probably the most convoluted part			

of the entire system. Certain system parameters that, if the student knew more about it, would enable a better understanding of the inputs that would be required to model real-world situations. The analysis took very long and if you didn't run it on the C drive it would crash. It is easy to make a simple mistake and get meaningless results.

Question 6:	Yes	Middle	No
Your recommendations for further adopting of FlowLab. Or any other comments.	NA	NA	NA

It would help if the student version of FlowLab could be purchased for use at home or on a laptop. More guidance in using the software or have manuals available in Keller. Use the FlowLab animation feature more often.... It would have been interesting if FlowLab could have usefully been incorporated into the boat project or the truck project. I would suggest doing a FlowLab portion as a prelab so that you know what your results should look like when you get to the lab. Then in your write-up you could compare your results. … Get a commercial piece of software that we may see after school. Like in EGR309 we used Ansys. It was aggravating, but allowed me to jump onto another FEA system and have a general concept of what was going on. Maybe we could just use Ansys and you could provide partially completed file to get us going.