Modernizing the ChE Curriculum via Interactive Visual Aids for Traditional Courses

By Prof. Roman Voronov
Chemical and Materials Engineering
New Jersey Institute of Technology

The goal of this project was to create stand-alone executable COMSOL (a multiphysics simulation suite) apps, that students and teachers across the world could use "out of the box" in order to demonstrate and learn the science behind fundamental engineering processes. The creation of such virtual teaching aids is especially relevant in today's uncertain world of the COVID-19 pandemic, given that most of the academic laboratory courses have been rendered impossible to teach by the shutdown. Each app is compiled for three different operating systems: Windows, MacOS and Linux. Please note that there will be a one-time installation of the COMSOL runtime libraries upon the first execution of an app.

1) **PLUG FLOW_TUBE_REACTOR**
   This application was designed to simulate a plug flow tubular reactor (PFTR) commonly encountered in chemical engineering labs and courses. It was written by Prof. Voronov's research assistant Chemical Engineering Senior Vasilios C. Halkias, who has won the 2020 International Association for the Engineering Modelling, Analysis and Simulation Community (NAFEMS) Americas & engineering.com Student Award for its development.

   windows https://drive.google.com/open?id=1Vb5QAubYr7WBNFT3_N6hnsIRx8yMWVC2&authuser=rvoronov%40njit.edu&usp=drive_fs

   linux https://drive.google.com/open?id=1VYBGoDNDKGZOx4NmPBE8q-EsNrq9Z6TS&authuser=rvoronov%40njit.edu&usp=drive_fs

   macos https://drive.google.com/open?id=1VZYzudy5e9cVPp9i38IKUTSwfL4idsPi&authuser=rvoronov%40njit.edu&usp=drive_fs

2) **3D PRINTER NOZZLE**
   This application was designed to demonstrate complex fluid flow and heat transfer occurring within a simple 3D printer nozzle, which is relevant to Structures and Properties of Materials and Additive Manufacturing courses.

   Windows - https://drive.google.com/file/d/13AmdGvbfP_PLfgZzltEuqs-28V-4FR33/view?usp=sharing
   Linux - https://drive.google.com/file/d/13G3bM2rD3rW4FIdzDuZFC7Ut5ji-DBQZ/view?usp=sharing
   MacOS - https://drive.google.com/file/d/13BPQlp-_f6pesmK7BdMs2m6bqOBe5a7J/view?usp=sharing

3) **REACTION YIELD ENHANCEMENT VIA BAFFLES IN 2D FLOW**

This application was designed to demonstrate how the introduction of baffles can affect a reaction occurring under flow in a simple 2D reactor. The user can run a parametric sweep over two selected parameters (e.g., baffle width and baffle height) and see how changing them improves or worsens the reaction yield (see 3D plot). The results can be used in order to optimize the reactor geometry in order to maximize the yield.

Windows
- https://drive.google.com/file/d/12U698hXsz8hf3m14vGOmOVt7WOKSR3cA/view?usp=sharing
Linux - https://drive.google.com/file/d/12V2ax0Qasgq6jJy7Okbh9AGH-ELQpcbr/view?usp=sharing
MacOS - https://drive.google.com/file/d/12adbsEJgNWrgVM8nunXlyKOe5LVL5Hl2/view?usp=sharing

4) **IMPELLER OPTIMIZATION IN A STIRRED TANK REACTOR**

This application was designed to demonstrate how an impeller morphology can affect the reaction yield in a stirred tank. The user can run a parametric sweep over the thickness and radius of the impeller and changing them improves or worsens the reaction yield (see 3D plot). Additionally, the app can export an STL file so that the students can 3D print the impeller of different sizes and try to reproduce the app's results in the lab. This is relevant for Unit Ops lab and Kinetics courses.

Windows
- https://drive.google.com/file/d/18Wj80FbVR0nC8h8iPn0KgX2c2QoVYTyL/view?usp=sharing
Linux - https://drive.google.com/file/d/18WddHHl3GO9RniQgQRJ6aP170ywy5CPe/view?usp=sharing
MacOS - https://drive.google.com/file/d/18XeDeR9DGpPSvhv4_18qaQSs_D0nQxqp/view?usp=sharing

5) **DISPERSION_FROM_A TOXIC_STACK**

This application was designed to demonstrate a classical chemical engineering problem that tracks how plumes and puffs of a toxic pollutant distribute down stream from a stack or a ground source that they've been released from. The students can plot and animate the results for various conditions tabulated in a textbook. The app is relevant to Safety and Design/Capstone courses.

Windows - https://drive.google.com/file/d/16f4Okf-DdVQ-xrlj3aO4_GtiMQQSO8CL/view?usp=sharing
Linux - https://drive.google.com/file/d/16csvPSTQzEfUgSjY4sUa3PQCjfGJalNR/view?usp=sharing
MacOS - https://drive.google.com/file/d/16k9XIMjJs3PYB3CxcZ1Y-6iNFxf-8eW4/view?usp=sharing

6) **LAMINAR_STEADY_PIPE_FLOW**

This application was designed to demonstrate a classical chemical engineering problem of laminar flow in a pipe. The students can visualize the flow field and get a feel for how changing the various input parameters affects the Reynold's number. The app is relevant to the Fluid Flow course.

Windows - https://drive.google.com/file/d/1-kvuPclM_qZARgM4l3F6jrhsnBOQ3sgC/view?usp=sharing
Linux - https://drive.google.com/file/d/1-fMaSygfw-FnG2cp0EH7QXJiNrKGqnT1/view?usp=sharing
MacOS - https://drive.google.com/file/d/1-bqQUu-7N-TrO972yvN3lS-Uq2zmj4Rm/view?usp=sharing

7) **LAMINAR_STEADY PIPE_ENTRANCE _FLOW**

This application was designed to demonstrate a classical chemical engineering problem of laminar *entrance* flow in a pipe. The students can visualize how the parabolic velocity profile develops within the entrance region. The app is relevant to the Fluid Flow course.

Windows - https://drive.google.com/file/d/1-DFt6gzhNLw72a7qFthsUQ-SVgTQleuq/view?usp=sharing
Linux - https://drive.google.com/file/d/1-0hcu2f8qwpqnRa0XSvaQ8yB29aBYZH5/view?usp=sharing
MacOS - https://drive.google.com/file/d/1-NnTIFmg-I7Tsfy6_VD0byAHhkBaC1cb/view?usp=sharing

8) **HEATED_PIPE_FLOW**

This application was designed to demonstrate a classical chemical engineering problem of laminar flow in a *heated* pipe. The students can the temperature profile evolves based on their inputs. The app is relevant to the Heat Transfer course.

Windows - https://drive.google.com/file/d/14m_K1XtfCbaRSRquzcn0q-mHsqJq9x1a/view?usp=sharing
Linux - https://drive.google.com/file/d/14q0skER4MbshB2_LtXsHrFdQgoFSxgeq/view?usp=sharing
MacOS - https://drive.google.com/file/d/15-jpk30s2p3LCIiRC2kyrl2fq1rUoCi7/view?usp=sharing

9) **MASSFLUX_PIPE FLOW**

This application was designed to demonstrate a classical chemical engineering problem of laminar flow in a pipe experiencing mass transfer. The students can the concentration profile evolves based on their inputs. The app is relevant to the Mass Transfer course.

Windows - https://drive.google.com/file/d/15KGhnW1yzSD7z8WLxCriS3VMXFFTxCM/view?usp=sharing
Linux - https://drive.google.com/file/d/15KhZBlgvUyHIaKE2vgW3UvZdJE74t7nc/view?usp=sharing

MacOS - https://drive.google.com/file/d/15N_iH24E1u83mHYt7y2PlzbBGtjPu_TI/view?usp=sharing

10) FRICTION LOSS IN PIPE_ELBOW

This application was designed to demonstrate a classical chemical engineering problem of laminar flow in a pipe elbow. The students can vary the elbow angle and various other pipe parameters in order to compare the simulation friction loss results to the correlations from literature. The app is relevant to the Unit Ops lab.

Windows - https://drive.google.com/file/d/16vQMGAVvoD-mOo4RidHdmibJVT7bMOiu/view?usp=sharing
Linux - https://drive.google.com/file/d/16vRkSkWN5GU6DS0tdXYeqcejyUnazeo7/view?usp=sharing
MacOS - https://drive.google.com/file/d/16xN53rKc4Anffi9X76903Ib8DmXLKC-k/view?usp=sharing

11) ORIFICE_FLOWMETER

This application was designed to demonstrate the inner workings of a classical chemical engineering *orifice* flow meter. The students can compare the simulation results to a solved textbook problem and/or to their lab measurements. The app is relevant to the Unit Ops lab.

Windows - https://drive.google.com/file/d/17dU8y7nMA0DwpvCpD9finGUwHrgMm8Yw/view?usp=sharing
Linux - https://drive.google.com/file/d/17craPRkCpt-WwcY7ltNSOTrI3qGrUnU5/view?usp=sharing
MacOS - https://drive.google.com/file/d/17efsl2ANE9lD2JQO_H8aN0CEjWVbvn8D/view?usp=sharing

12) VENTURI_FLOWMETER

This application was designed to demonstrate the inner workings of a classical chemical engineering *venturi* flow meter. The students can compare the simulation results to a solved textbook problem and/or to their lab measurements. The app is relevant to the Unit Ops lab.

Windows - https://drive.google.com/file/d/14N_9tjbLv_vSM7ue5krBqOgPRgubxSKO/view?usp=sharing
Linux - https://drive.google.com/file/d/14MmwcPhW8yGsDapR2rhjc2fVbsvRNkxx/view?usp=sharing
MacOS - https://drive.google.com/file/d/14Cgi8hRNea8CsRaOYkBuOskCBinzIewk/view?usp=sharing

13) **DIFFUSION_INTO_A_FALLING_FILM**

This application was designed to demonstrate a classical chemical engineering problem of gas diffusion into a falling liquid film. The students can compare the simulation results to a solved textbook problem and/or to their lab measurements. The app is relevant to the Mass Transfer course.

Windows
- https://drive.google.com/file/d/160rvz6gIv0pPHo8TRaISluLF1TPjh6Ys/view?usp=sharing
Linux - https://drive.google.com/file/d/15zp1xvKROhZNSKbQekSHPZ7vxpMbw7mn/view?usp=sharing
MacOS - https://drive.google.com/file/d/169zMtwjg0QyFeNX845nmO3zYNUHLaYg4/view?usp=sharing

14) **FLOW_AROUND_CAR**

This application was designed to demonstrate a "fun" chemical engineering problem of calculating the drag coefficient around a streamlined body (in this case a car). The students are then able to compare the simulation results to a drag coefficient plot for a rounded nose cylinder.

Windows - https://drive.google.com/file/d/11KWu3hQvop4s-zCjUZKONUpMX44rmVns/view?usp=sharing
Linux - https://drive.google.com/file/d/11Lg-rIPL9_1j4AS6MlpH17VZqqfdPJwE/view?usp=sharing
MacOS - https://drive.google.com/file/d/11QRm_2CkYtqnEVqp8XeZAS6TeOolIl8O/view?usp=sharing

15) **FLOW_AROUND_AN_AIRPLANE**

This application was designed to demonstrate a "fun" chemical engineering problem of calculating the drag coefficient around a less streamlined body (in this case an airplane). The students are then able to compare the simulation results to a drag coefficient plot for a blunted and rounded nose cylinders.

Windows
- https://drive.google.com/file/d/10rosNa88cdjrcHlCe6zpeozInjqQm58_/view?usp=sharing
Linux - https://drive.google.com/file/d/10iYXKnql6sNyMFXrSBeLxa_PoKWP_t9w/view?usp=sharing
MacOS - https://drive.google.com/file/d/10qqJFHg0wbX9ZVHKtbVa-HaPJk470h28/view?usp=sharing