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RESEARCH ARTICLE

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Training Apps, Strategies, and Modules as a Key Academic for New Engineering Textbooks on Creative Thinking

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Abstract. Fundamental engineering principles must be taught proficiently in universities in order to educate the next generation of engineers. The project's execution goal is to use interactive visual aids to modernize existing engineering courses at Elmergib University. The use critical engineering labs, has become increasingly challenging. Visual teaching aids and virtual training materials are in high demand among instructors to help students learn remotely. COMSOL is an exciting visual tool for training students about physical phenomena, owing to its strong Multiphasic setup and very user-friendly user interface. Regrettably, even with extensive online instructions, a learning curve limits many instructors from adopting it into their classes. Similarly, some universities might up to purchase expensive license packages for the most significant simulators. The Edali et al. research group of Elmergib University aims to construct self-contained COMSOL executable runtime Apps through their simulation application development initiatives. By downloading them for free from anywhere in the globe, you are able to utilize these App libraries "out of the box" to understand the science underlying the simulation. Each app is designed for Windows and macOS. The free COMSOL runtime libraries must be installed only once when users launch an application for the first time. Experimenting with alternate ways to share knowledge platforms and studying creative approaches to organize student-instructor interactions to improve learning are two examples of educational media creation advances. That promotes technology-based resources and techniques in education through computational engineering projects. The authors' research advances based on experiences in student-instructor interactions improves the engineering curriculum.
Keywords: Research on Educational Key Technology, Virtual Learning Resources, Applications for simulation, and runtime for COMSOL.

1.Using COMSOL Applications the Modern Technology in Engineering Education to Promote Creative Thinking

Using modern technology in engineering education, such as COMSOL apps, can be a tremendous approach to stimulate student innovation. COMSOL is a finite element analysis program that allows for the modelling and simulation of a wide range of engineering and scientific events. Here are some ideas for using COMSOL apps to encourage creativity in engineering education:

1.1.Interactive Simulations

Interactive simulations utilizing COMSOL apps can be a helpful teaching tool in engineering. COMSOL is a powerful finite element analysis software that can model and simulate a wide range of physical events. Here are some examples of how interactive simulations using COMSOL apps might assist engineering education. Interactivity: Interactive simulations are naturally engaging. They give students hands-on experience by allowing them to modify parameters, monitor real-time changes, and experiment with various scenarios. This involvement has the potential to boost students' motivation and interest in engineering subjects. Simulations can be used to reinforce theoretical topics taught in the classroom. Students gain a greater understanding of how these concepts work when they see them in action, which leads to better retention and comprehension. Understanding Complex Systems: Engineering frequently deals with complex systems and interactions. COMSOL apps can help students understand complex concepts and relationships by simplifying the visualization of these systems. Examining and experimenting Students can utilize COMSOL tools to explore "what if" scenarios. By altering the variables and designs, they can explore and find creative solutions to issues. Risk-Free Education Simulations offer a risk-free environment for exploration. Students are allowed to make mistakes and learn from them with no consequences in the real world, which encourages a growth mentality and stimulates creativity. Applications in Different Fields COMSOL software, which covers a range of engineering disciplines, can be used by students to examine cross-disciplinary applications. This broadens their vantage point and inspires them to use original thought while resolving issues that cut across numerous disciplines. Relevance to the Real World: Engineering issues in the Real World can be simulated. Students can work on assignments that reflect business issues, preparing them for real professional applications. The ability to customize COMSOL apps allows educators to create simulations that are tailored to certain learning goals or difficulties. This adaptability enables innovative lesson design and satisfies specific educational requirements. Interactive simulations can be utilized in group situations to encourage collaborative learning. Students can collaborate to find solutions to issues, exchange concepts, and benefit from one another's experiences. Evaluation of Simulations can be used as an evaluation method to gauge students' capacity for critical thought, problem-solving, and application of theoretical knowledge to real-world contexts. Assessments can be created to promote original thinking. Feedback and iteration: Simulations can give students immediate feedback, enabling them to hone their tactics and test out other ideas. Students may be inspired to think creatively and to consider many ideas as a result of this iterative process. The COMSOL apps from Accessible Learning can be used remotely, allowing students to participate in interactive simulations from any location with an internet connection. This accessibility promotes learning flexibility and supports a variety of learning methods. Engineering education can be improved by using COMSOL apps to make the learning process more interactive, interesting, and useful. It gives students the tools they need to think creatively, acquire problem-solving techniques, and get ready for the difficulties they'll face in their future engineering professions.

1.2.The Challenges of Using Critical Engineering Labs

It is true that using crucial engineering labs has gotten harder for a variety of reasons. Due to health and safety concerns, several educational institutions had to restrict access to physical labs during the COVID-19 pandemic. This forced educators to use virtual laboratories and remote learning, which, although useful, cannot completely replace the hands-on learning that occurs in essential engineering labs. Some schools and institutions found it difficult to give students access to essential engineering labs because of financial restrictions, space restrictions, or faulty equipment even before the pandemic. This restriction may make it more difficult for students to learn practically. Costs of equipment and It can be expensive to update and maintain essential engineering lab equipment. This cost strain may result in out-of-date or broken equipment, which would prevent students from participating in cutting-edge investigations. Safety Guidelines for Some harmful processes or materials are used in crucial engineering labs, necessitating stringent safety procedures and specialized training for students. Access to these labs may be further hampered by these security concerns. The lack of lab instructors, teaching assistants, and technological support staff may frustrate the efficient running of key engineering labs. Students may fail to conduct experiments efficiently if they are not properly guided and supported. Space constraints of engineering lab space are limited, and scheduling conflicts can occur when many courses and programmes seek the use of the same facilities. This might lead to overcrowding in labs or limited access for students. Technological advances beacause of the rapid speed of technical improvements in engineering domains, lab equipment can quickly become obsolete. It might be difficult for educational institutions to keep up with these improvements and provide students with up-to-date equipment. Some critical engineering laboratories' sustainability issues may entail methods or experiments with environmental consequences. Sustainability considerations are increasingly being considered by educational institutions, which may limit the scope of certain lab operations.

Regardless of these issues, educators and institutions can take several actions to solve them and continue to provide vital critical engineering lab experiences. In-person and virtual laboratories can be combined in hybrid techniques to make the best use of available resources while maintaining safety and accessibility. Collaboration with industry partners or neighbouring institutions to share access to specialized lab facilities and equipment. When physical labs are not available, invest in high-quality simulation and virtual lab systems to enhance practical learning experiences. Remote lab access refers to systems that allow students to control lab equipment from a distance, giving them hands-on experience even when on-site access is limited. Funding and grants are being sought to upgrade lab equipment, improve infrastructure, and improve the safety of essential engineering labs. Flexible lab scheduling is used to accommodate different courses and programmes, ensuring that all students have equal access. To ensure safe lab practises, thorough safety training programmes for students and teachers are being developed. Sustainability efforts aimed at incorporating sustainable engineering practises into laboratory tests and research to address environmental concerns. Adapting to the changing landscape of engineering education and solving the problems of key engineering labs necessitates ingenuity, inventiveness, and a dedication to providing the greatest possible learning experiences for students.

1.3.Creativity as an essential skill for 21st-century learners

Creativity is widely acknowledged as a necessary quality for 21st-century learners. The ability to think creatively and solve fresh challenges is critical for personal, academic, and professional success as the world becomes more complicated and dynamic. The references you gave emphasize the significance of encouraging creativity in education and highlight several techniques for doing so. Traditional abilities such as memorization and rote learning are being complemented with a higher emphasis on critical thinking, problem-solving, and creativity in the twenty-first century. These abilities are regarded as more relevant for dealing with today's difficulties. Investigation and recognition of Craft [1], Cropley [2], Harris [3], and Henriksen [4, 5, and 6] are examples of researchers. As well as others have performed research to better understand the nature of creativity and its significance in education. They've given us some great ideas about how to foster and integrate creativity into the curriculum. Educational experiences that are innovative Traditional teaching approaches are not the only ways to promote creativity in school. They entail creating learning experiences that inspire students to think creatively, question assumptions, and explore different points of view. Blending in and out of the classroom to foster creativity both within and beyond the classroom.

This approach recognizes that learning is not limited to formal educational settings and that creativity may flourish in a variety of settings. Creativity as a process is not an innate feature; it may be developed through a process of producing ideas, developing them, and applying them to real issues. This methodical approach to education encourages experimentation and risk-taking. The function of the instructor as an educator is critical in promoting creativity. They must foster a welcoming and inclusive learning atmosphere, encourage students to pursue their passions and provide chances for self-expression and cooperation. Creativity frequently develops at the junction of several fields and ideas through cross-disciplinary approaches. Cross-disciplinary thinking can result in breakthroughs and novel solutions. Assessment and recognition while gauging creativity can be difficult, it is critical in education to recognize and reward creative ideas. Traditional assessment methods may need to be modified in order to accurately capture creative achievements. Creativity is a life-long ability that benefits people throughout their lives. Promoting creativity in school prepares students to adapt to changing problems and to continue learning after they complete their official education. In an interconnected world, innovation is not constrained by geographical barriers. Global viewpoints and varied cultural influences should be considered in educational practices that develop creativity.

In this regard, creativity is a critical skill for persons in the twenty-first century, and educators and academics are actively investigating strategies to encourage and assess creativity in educational contexts. Educational institutions can educate students to flourish in an ever-changing environment by adopting innovative teaching approaches and recognizing the value of creative thinking.

2.Learning by Doing Techniques

The concept of learning by doing has been recognized as one of the most successful techniques of teaching engineering students, and this idea was previously embraced as a pedagogical in this study. The perception of a notion, accompanying theory, and requisite modeling expertise are all rendered by computer simulation. This innovative teaching approach aims to promote an understanding of heat and mass transfer, fluid mechanics, transport phenomena, and reaction engineering concepts through theoretical assessment via modelling with variable parameters optimization utilizing COMSOL solution algorithms. Engineering students can better grasp the concept by modelling equations in software and simulating to arrive at a problem solution, then validating it through simulation tests. Introducing students to the latest and most cutting-edge innovative technology that the industry is adopting and moving toward. As needed, students investigate to identify and master new technologies. The state-of-the-art COMSOL multiphasic simulation program was used to create a pre-planned extensive utilization of new App-making features. The experiment of teaching through classroom lectures is a technique of learning information that has recently attracted the curiosity of various engineering training communities. This strategy was initially created to improve students' learning by replacing traditional lectures with a better-simulated App environment. This critical teaching technique allows students to access primary subject material using educational technology such as computers, tablets, cell phones, and other devices. The teaching philosophy will enable professors to set aside more class time for interactions with students and addressing questions on the lecture's topics. The requirement to grasp the approach of solving real-world issues drives the usage of App teaching classroom tactics in engineering areas. Because engineering typically focuses heavily on hands-on experiments and projects and higher learning degrees, it lends itself to this innovative educational method. This work's authors published four separate research articles for four other chemical engineering courses, heat transfer [7] and transport phenomena [8], fluid mechanics [9], and the project of the curriculum developments [10]. They concluded that demonstrating this App teaching publication was more effective than traditional courses in terms of route content, student performance, and students' grasp of their learning experience. The issue arose that funding to pay for the software's expensive license use has to continue using this App teaching technique. For that reason, the authors of this work worked to build these prepared Apps to be running under a free version of runtime COMSOL software. This research paper makes that point and spreads the App creation as free Apps for users worldwide through a website created while preparing this paper to publish the produced free runtime Apps with detailed videos and illustrations [11]. Details of the free runtime COMSOL Apps creation process authors followed will be illustrated.

Instructors usually spend around forty contact hours with students in a class to teach the course information by handing out notes and allowing students to use their time with something more productive. Practice is the only method to enhance a skill such as writing, critical thinking, or solving fluid mechanics problems: try something, see how well or poorly it works, and reflect on how to improve it, then try it again to see if it works better. Why not provide students supervised practice in the activities they will be required to complete on assignments and examinations during those contact hours to assist them in improving skills. In another way, why not include active learning in the classroom at various moments during the day, such as when students answer questions, create a flow chart, diagram, or map, sketch a problem solution, or solve all or part of a problem. Execute all or parts of a formula derivation, predict a system reaction, assess an observation or experimental result, criticize a design, troubleshoot, brainstorm, and ask questions. Students can be encouraged to work individually or in groups for a given length of time; they can be asked for varied voluntary responses. If required, the instructor can provide the proper response. This active learning strategy energizes students, and academically underachieving students benefit from peer tutoring. By instructing others, stronger learners get a deeper understanding of the subject. COMSOL multiphasic is a robust cross-platform finite element analysis and simulation software package with an intuitive user interface, making it an attractive visual accessory for teaching physical phenomena to students. Several textbooks use COMSOL for undergraduate and graduate chemical engineering courses [12].

COMSOL introduced a compiler add-on to create stand-alone executable of Apps built using the application builder tool. These compiled Apps include the entire runtime libraries so that the recipients do not need to purchase any software to execute the Apps. The Apps enable instructors to share their knowledge and expertise in stand-alone modeling and simulation Apps that can be deployed to anyone through cloud computing environments. Professionals may now construct lightweight programs that download and install COMSOL Runtime on demand as of the latest version 5.6. When the size of the Attachment Exceeds the Maximum one receives the notification that the email attempting to send has an attachment that's too large because the maximum size of an email is generally in the region of 5 to 50 MB, this is quite likely. When the COMSOL Compiler was first released, the built

standalone executable files contained all of the files needed to run the simulation. As a result, file sizes surpassed 300 megabytes, which is a bit much for an email. The application developer has the option of including or excluding COMSOL Runtime in the standalone application executable when compiling in version 5.6. If all other factors are taken into account, the file size can now be less than 10 MB tiny enough to be sent as an email attachment. The installation process is simple once the lightweight standalone executable file has been prepared and emailed to a colleague or customer. An online installer will automatically download COMSOL Runtime the first time a developed application is accessed, and its download process should be done only once. Unless the built program was produced with a different version of COMSOL multiphasic, no new installation is necessary the next time it is used. If the application's user does not have an internet connection, the developer can utilize the Embed option to include the COMSOL Runtime in the executable file.
Associate Professor Edali of Elmergib University created a sample of Figure 1 showing a screenshot of a runtime COMSOL App. The App studies the total heat flow through a brick wall and is estimated using the one-dimensional conductive heat transfer governing equation in this basic App as shown in Figure 2, which is designed to explore steady-state conductive heat transfer. The goal of the analysis is to help students comprehend the issue's two halves, the first of which provides theoretical background and the second of which is divided into multiple numerical analysis tabs.

Figure 1: Screenshot of a runtime COMSOL App.

3.Heat Transfer Apps ‘case studies’

A screenshot of a COMSOL App shown in Figure 2, shows the total heat flow through a brick wall is estimated using the one-dimensional conductive heat transfer governing equation in this basic App designed to explore steady-state conductive heat transfer. As illustrated in Figure 2, the App is built so that students can simply explore the two portions of the issue, the first of which gives theoretical background and the second of which is separated into different numerical analysis tabs such as geometry, meshing, temperature profile, and so on.

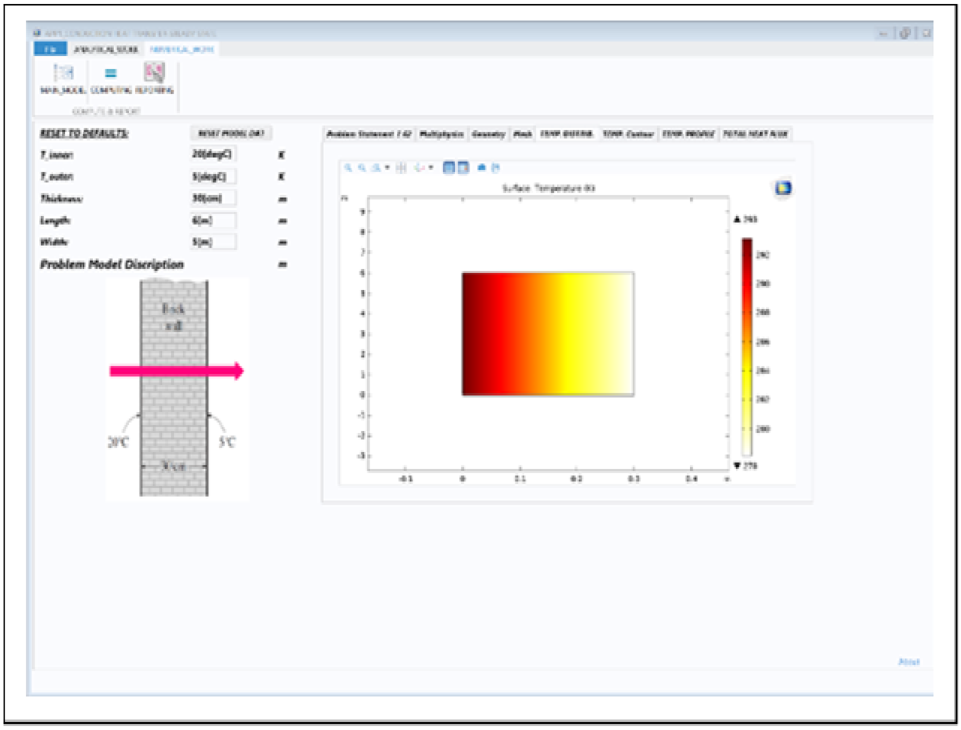

Figure 2: App1 discusses total heat flow through a brick wall.

4.Application Builder In COMSOL

Engineers may use the application builder to construct simple Apps based on their simulations. The engineer who creates the App customizes the user interface and controls the inputs and outputs that the App's user can alter. Experts create Apps that only provide the characteristics necessary for the design of a specific item or process. The applications then make the simulation engineer's knowledge available to everyone participating in the design and production processes in the firm, spanning all engineering disciplines. Product designs and procedures may be enhanced more efficiently and effectively with more professionals having access to simulation.

The application tree is created up of the inputs' main window, forms, events, declarations, methods, and library nodes, as illustrated in Figure 3. The input node contains sub-nodes of the type of application arguments. They can be used as input parameters when executing the program from the operating system's command line. The primary window node is the top-level node in the user interface and represents an application's main window. There is a window layout, a primary menu specification, and an optional ribbon specification. The normal complement of graphical user-interface widgets as in Figure 4, is available in the form editor such as buttons, checkboxes, combo boxes, radio buttons, text boxes, sliders, and tables. It also has a progress meter, a message log, an equation widget that displays structured LaTeX equations, and a results table, which are all particularly useful in a modelling application.

Forms may be collected into a form collection, which can then be chosen as the primary form, which will be displayed every time the app is launched. Members of the collection may show as selectable tabs, items in a table, or panes inside a single window on the main form. As a consequence, the app depicted in Figure 2 was created. It contains a toolbar at the top and distinct pages for the activities of geometry definition, model execution, and results from a presentation. The print head's pixel count and size may be specified in the first form of the collection, which then draws the print head. It not only generates the geometry but also resizes it to fit in the graphics window, unlike the simpler software. The meshing and solving activities are completed when users click the Compute button, and the graphics window is changed to a false colour representation of the simulated surface temperatures. A progress bar is shown in the lower right corner of the screen to measure progress during the solution. When the model is completed, it emits a chime and generates numerous pages with more findings. One page shows the temperature profile across the center of the image by cutting through the 2D surface temperature data in 1D.

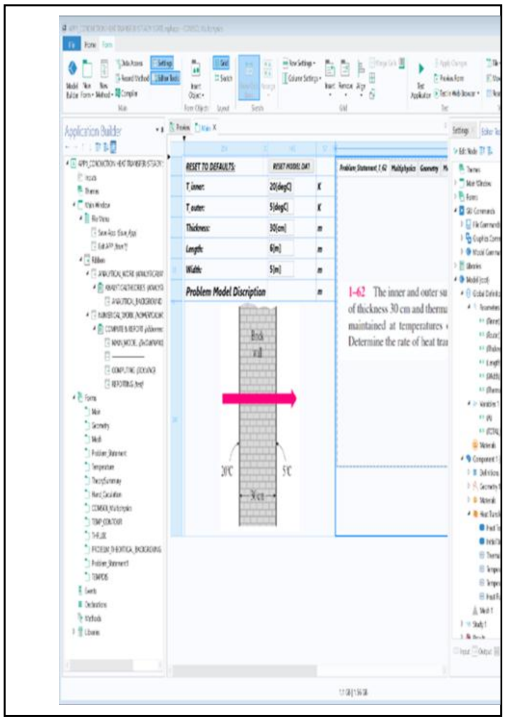

Figure 3: Application tree is created up of the inputs main window and forms.

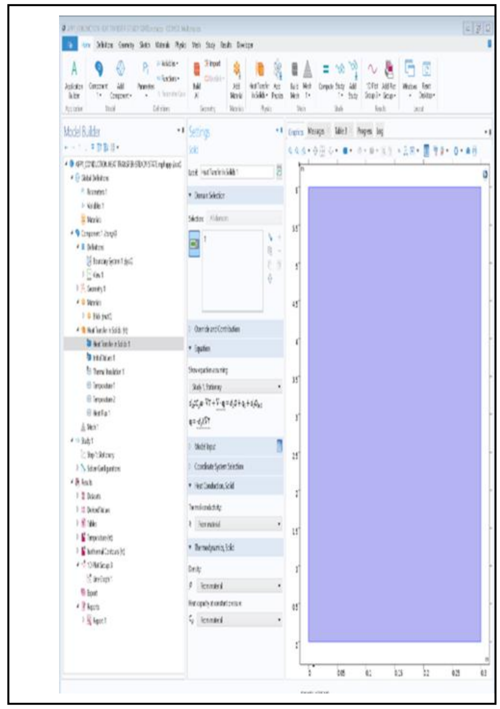

Figure 4: App graphical user-interface widgets in the form editor such as buttons, check boxes, combo boxes, radio buttons, text boxes, sliders, and tables.

5.Compiling And Running Stand-Alone Applications

The modeler may utilize the application builder to remove the detail-oriented tools that were used to create the model and create a more accessible program, an App that is intuitive and simple to use. App designers must make a few choices to compile a program. Set an output directory to save the executable files after they've been compiled. In most cases, the runtime option may be left at download. All of the COMSOL Multiphysics software components required to execute the application as a stand-alone program are included in COMSOL Runtime. The Runtime option controls how the COMSOL Runtime environment is kept and how the generated program behaves when it is launched for the first time on a machine. If this option is selected, the COMSOL Runtime environment files will be downloaded the first time a user launches the built program, a service provided by COMSOL. There will be no download if the COMSOL Runtime environment already exists on the computer with the same version number. Platform options decide which target-platform executable should be built during compilation. The executable extensions for the Windows operating system will be (.exe). For macOS, a (.tar) archive is produced; this archive needs to be unpacked to extract the software on macOS. Icon for Windows allows designers to customize the desktop icon. The splash option allows the provision of a BMP image file as in Figure 1 in the case study of this paper to be shown during startup. After compilation, the executable file will be available in the output directory in the Windows operating system as in Figure 5. When a built application is executed, such as by double-clicking the.exe file on the Windows operating system, a splash screen appears, and the application runs. If it is the first time the program is run on the computer, a click-through agreement and a progress box will show up for the Initializing Installer as a screenshot of a startup progress window as in Figures 5 and 6. The COMSOL Runtime Installer window appears after a short period, as seen below in Figure 7. The COMSOL Runtime Installer and its click-through agreement are only displayed once, and they are not displayed the following time you run the same program. If you launch another program on the same machine that was created using the same compiler version and the same version of the COMSOL Runtime, the click-through agreement and startup progress box will not appear. Clicking Next to specify the location of the COMSOL Runtime files, then click Install, as seen in Figure 7 below. The installation takes a few minutes, and after it's finished, the installer invites the user to run the program. The main window's settings allow the application's designer to choose how this information is accessed as in Figure 8. A designer can turn his application into a stand-alone program with all the capabilities needed to run it using the COMSOL compiler. This strategy gives the user the maximum flexibility because the end user of his application will not require the expensive licenses of COMSOL Multiphysics or COMSOL Server to utilize it. The produced software can then be run by that user and anybody else to whom the designer has granted authority to distribute the built application anywhere in the world, both inside and outside the user institution.The findings of simulation software like COMSOL Multiphysics may drastically save design time by lowering the number of experiments or product testing, for example. Simulation software, on the other hand, is not a substitute for real-world testing. This is particularly critical if there is a danger of bodily or environmental harm.

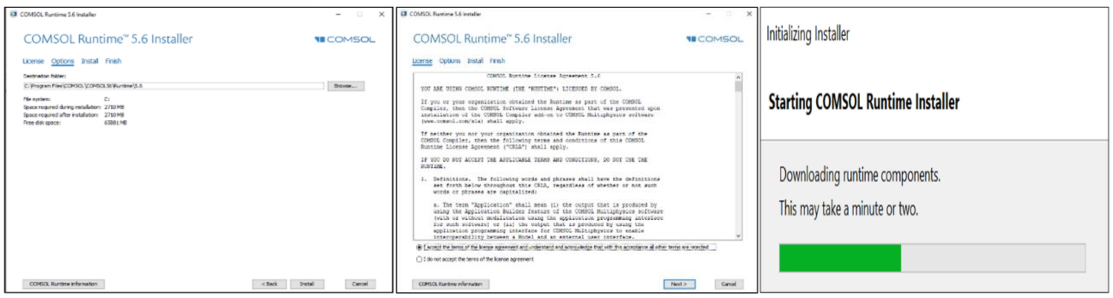

Figure 5, 6 and 7: Screenshot of a startup progress window for the case study App1, COMSOL Runtime Installer window

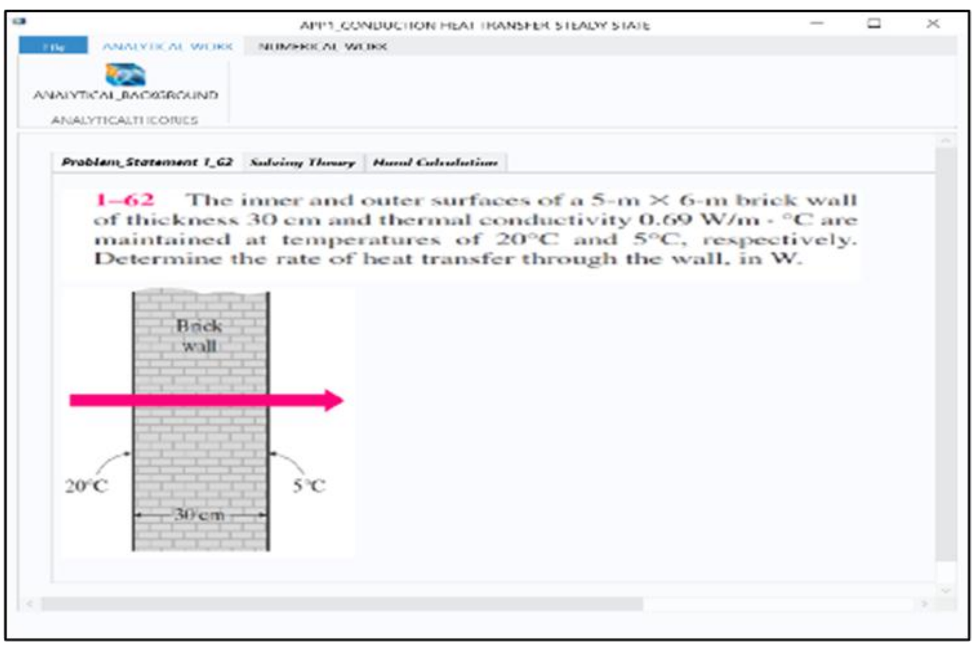

Figure 8: The main window's settings allow the application's designer to choose how information is accessed

6.Conclusion

This research was to expand and solidify students' understanding of chemical engineering students with the most significant fundamental courses at the undergraduate level through their learning process. An introduction to developing the course Apps was using simulation methods and technologies as an advanced teaching aid.

COMSOL Multiphysics used the built-in App builder function to generate these Apps. COMSOL Multiphysics' installed APPS is an excellent tool for achieving this aim. This research shows that after students manage the input data, the visible outcomes in the Apps may be changed, and as a result of their adjustments, they can generate several scenarios depending on their physics assumptions. The main aim of this project was to create stand-alone COMSOL Multiphysics simulation suite packages that students and teachers all around the globe could use right away to demonstrate and learn the science behind important engineering processes. Considering numerous academic laboratory courses have been made unteachable owing to the closure, the introduction of such virtual teaching aids is especially important in today's uncertain COVID-19 pandemic environment. Each piece of software is designed to run on either Windows or macOS. It's worth mentioning that when a program is started for the first time, the COMSOL runtime libraries are only installed once. The research team of this work created and examined the produced Apps and their teaching methodologies and their teaching philosophy presentations. They were subsequently aided in their use in classrooms and published on a website by the chemical engineering research group at Elmergib University as illustrated in [15], which enables any professor or engineering student anywhere globally with extra information on the teaching methodology.

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Professor Elkamel of Waterloo University offered academic and financial assistance for the use of the COMSOL software simulator, which the authors used to create the instructional Apps. The authors' creativity group's efforts in collating all teaching tool details and their time spent creating most of the work into the teaching website referenced in this paper, especially Mr. Sahem, are deeply appreciated. Associate Professor Edali of Elmergib University's chemical engineering department created and examined the produced Apps and their teaching methodologies and their teaching philosophy presentations.

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