Computation of the stiffness matrix for plane strain element

Learning Outcome	Criteria	Poor (0-3)	Average (4-7)	Beyond expectations (8-10)
Create a Notebook reporting the effects of the element's geometry in the stiffness matrix (20%).	**Notebook Design.** *Evaluates the student's capability to present in a clear and articulated form the connection between theoretical elements of the stiffness matrix and the geometry of the element.* Does the notebook establish the differences between theoretical elements belonging to the model of theory of elasticity and those strictly related to its approximation in terms of the finite element method?	The notebook is available but does not follow a well-articulated flow that separates general theoretical concepts from aspects of the implementation.	The notebook is available, and theoretical and computational aspects are differentiated but there are still some weakness in connecting conceptual ideas to its numerical approximation.	Presents a nicely structured notebook where the most relevant aspects of the theory are first covered without running into redundancies. It establishes a clear connection between the theoretical elements and how these are represented numerically an uses the proper examples to emphasize these connections.
Implement a code to compute the stiffness matrix of finite elements representing plane strain idealizations in the theory of elasticity (10%)	**Program Execution** *Evaluates the student's ability to implement codes that can be effectively used in typical finite element computations.* Does the program execute? Is the program efficient and general enough to evaluate the stiffness matrix for elements with various geometries? Is the program general enough in such a way that it can be easily modified to consider elements of different order?	Program does not execute or if executes it does not produce the right results	The program executes and produces correct results for the reported cases.	Program is free of syntax errors that impede execution and produces results for a very general set of input parameters.
	Program Structure *Evaluates the design and implementation aspects of the code.* Does the code separate independent tasks in the correct subroutines in such a way that optimizes their	The Program is incomprehensible or uses an algorithm that is so particular that only works under strongly restrictive conditions	Although the program contains subroutines there are still some difficulties when identifying independent tasks that can be used to structure the code.	The program makes a good identification of independent tasks that can be placed in independent general subroutines; it also follows an

	subsequent use? Does the code take advantage of Python's intrinsic functionalities in such a way that it avoids unnecessary implementations increasing efficiency?	introducing complexities when trying to extend it to elements with other inherent interpolation schemes	The program still contains unnecessary blocks of code that can be replaced by efficient Python libraries.	structured approach that facilitates its extension to other elements and physical models. The code includes a well-balanced number of comments and error traps making it highly robust
Use indicial notation to write the discrete version of the virtual strain energy (10%). - Use the implemented subroutines to conduct a study on the effect of the geometry of the element in the stiffness matrix (60%)	**Deployment of Disciplinary Concepts** *Evaluates the student's ability to formulate finite element algorithms using generalized indicial notation*. Does the student recognize the difference between elements pertaining to the elasticity model and those associated to the finite element method? *Evaluates the student's ability to establish relevant conceptual connections between mathematical elements and its numerical approximation?* Does the student recognize the Jacobian tensor as the fundamental mathematical component governing the geometry of the different finite elements?	Does not show the fundamental steps in the derivation of the stiffness matrix and its connection to the virtual strain energy.	Provides the stiffness matrix using index notation but still contains weaknesses in connecting fundamental concepts of the numerical implementation and the virtual strain energy.	Makes perfect use of the indicial notation, separating physical and numerical terms. Uses matrix notation in simplified form to show how the model is treated in the computer implementation.
	Interpretation of results *Evaluates whether the student can interpret the program results in terms of the numerical approximations involved in the computation of stiffness matrices*. Does the student arrive at general conclusions regarding the connection between the element geometry and the resulting	The student does not provide general results and conclusions that can be applied to more complex cases.	The student provides conclusions but does not uses a wide enough family of parameters maintaining the conclusions still restrictive to particular cases.	The student considers relevant examples, including extreme cases which allow him to identify the most important conceptual elements governing the effect of the element geometry in the resulting

	stiffness matrix?			stiffness matrix.