In the element:

$$u = \begin{bmatrix} N_1 & N_2 & N_3 \end{bmatrix} \begin{bmatrix} u_1 \\ u_2 \\ u_3 \end{bmatrix}$$

$$\varepsilon = \begin{bmatrix} \frac{\partial N_1}{\partial x} & \frac{\partial N_2}{\partial x} & \frac{\partial N_3}{\partial x} \end{bmatrix} \begin{bmatrix} u_1 \\ u_2 \\ u_3 \end{bmatrix} = [B]\{u\}$$

$$[B] = \begin{bmatrix} \frac{4x}{\ell^2} - \frac{1}{\ell} & -\frac{8x}{\ell^2} & \frac{4x}{\ell^2} + \frac{1}{\ell} \end{bmatrix}$$

The matrix $[D]$ is the scalar Young's modulus.

Therefore

$$\int_{-\ell/2}^{\ell/2} [B]^T [D] [B] A \, dx = \int_{-\ell/2}^{\ell/2} \begin{bmatrix} \frac{4x}{\ell^2} - \frac{1}{\ell} \\ -\frac{8x}{\ell^2} \\ \frac{4x}{\ell^2} + \frac{1}{\ell} \end{bmatrix} EA \begin{bmatrix} \frac{4x}{\ell^2} - \frac{1}{\ell} & -\frac{8x}{\ell^2} & \frac{4x}{\ell^2} + \frac{1}{\ell} \end{bmatrix} dx$$

$$= EA \int_{-\frac{\ell}{2}}^{\frac{\ell}{2}} \begin{bmatrix} \left(\frac{4x}{\ell^2} - \frac{1}{\ell}\right)^2 & -\frac{8x}{\ell^2}\left(\frac{4x}{\ell^2} - \frac{1}{\ell}\right) & \left(\frac{4x}{\ell^2} - \frac{1}{\ell}\right)\left(\frac{4x}{\ell^2} + \frac{1}{\ell}\right) \\ & \left(\frac{8x}{\ell^2}\right)^2 & -\frac{8x}{\ell}\left(\frac{4x}{\ell} + \frac{1}{\ell}\right) \\ \text{Sym} & & \left(\frac{4x}{\ell^2} + \frac{1}{\ell}\right)^2 \end{bmatrix} dx$$