Investigating how social justice framing for assessments impacts technical learning

Supplemental Information

Appendix A – Modified Bloom's Taxonomy

In our study, we used a modified Bloom's Taxonomy scale to evaluate student critical thinking skills about social justice when prompted and unprompted in an exam. Table A1 provides examples of student responses for each of the Bloom's levels under the prompted and unprompted exam questions.

Table A1: Example of responses for students' incorporation of social justice into technical decision making.

Bloom's level	**Description**	**Example Responses (Prompted) -** In class, we have talked about many equity, equality, and social justice issues. Choose AT LEAST ONE social justice topic and trace out the implications of an investment strategy. In other words, how will the investment decisions you will have to make in your future career be impacted by or impact one or more of these social justice topics? Your answer should touch upon the social justice or equity implications that any engineer or analyst should be tracking and presenting to the decision makers considering the investment decision. How will you evaluate impact and uncertainty?	**Example Responses (Unprompted)** - Assume that you are working at a water pipeline company, which monitors water and sewage flow. You need to decide where to invest some of your company's money. There is uncertainty about how many people will be impacted by different investments, the risk of lead and harmful chemicals leaking into the pipes, the final costs of different investment strategies, and many other factors. To help you with this decision, a team member has created some models of how your investment would impact company profits. How would you evaluate the suitability of the economic and decision models for informing your investment decision?
0	No social justice	As an example investment project, I am considering investing in a commercial development. One social justice topic this would impact is the cost of property around the area.¬† The investment analysis would consider the interest rate associated with buying and developing a property.¬† I would also need to consider corporate and property taxes.¬† This development would also have a salvage value that is impacted by depreciation. The social cost of this development would include the type of business in the commercial property and whether the existing community would benefit from its presence. If it is a large developer like Google, for example, it may raise the cost of	Evaluating the suitability of the models for decision making: * The first step is ensuring that the goal is clear. In this case, it might be finding the most secure (least risky) investment. * Does the model clearly capture the assumptions made and uncertainty? Complex enough to capture important information. * Next would be determining which models actually model what I would need to know and incorporate all stakeholders.

		property and displace smaller businesses.	
1	Remembering and recalling facts	One thing that we discussed in class was the exploitation of prison labor in everything from making mattresses to fighting fires. Despite the promise of prison labor to provide inmate stability/purpose and cheap labor - it proves to be mostly exploitive. Inmates who fight fires are unable, in most cases, to get a job as a professional firefighter after their release. The prison population is also disproportionately people of color and prison labor can essentially have employed as modern-day slavery. Many of these individuals are also incarcerated for non-violent crimes and serve longer sentences because of their skin.	Because this is a clean water project; it is considered a service project which would consider social benefit more than profit. I would consider some factors like the cost of clean water, how many people have access to the water, and the efficacy of the system used to clean the water. The public infrastructure is also significant to the private company because they would need to have proper pipes to get the water to people. One consideration would be the lifetime of the system and maintenance cost. Other financial considerations with investing include interest rate, inflation, and deprecation. All these considerations, including the economic cost and the social cost, could be put into a net present value model that would provide a positive or negative value associated with investing in the project. This would show profit and inform the decision-making process.
2	Explains ideas and concepts	In a dam project, besides the routine geological investigation that is needed where impact of the project on the habitats of local species and local climate is reported, social justice regarding the residents living downstream should also be considered. Building a dam usually requires disrupting the current course of a river. An area might need to be flooded (residents must be relocated) before the construction, or an area that used to have access to the water will not after the dam is built. The quality of life of the affected residents must be evaluated against the benefit of	Considering sustainability, I would take social, environmental, and economic values into next present value calculations and think about all stakeholders. From the environmental aspects, I would estimate the damage to the environment (water body, air quality, etc.). From the social aspect, I would consider the clean water benefits brought to the community (such as the less money and time they would spend on medical services). Also, the impact of harmful leakage, which could lead to a poor health condition.

		electricity generated from clean hydro power. The possibility of failure of the dam must also be considered, for the failures can induce natural disasters such as flooding and land sliding, which can cause severe social-economic losses.¬†	
3	Apply, use information in new situations	Social justice topic: federal highway impacts on poverty. As we discussed in class, placement of federal highways or roads can exacerbate poverty. Investment decisions such as where to place a highway, its width and length, or where cars can enter and exit, can divide communities and isolate or disenfranchise low-income communities. One local example is the road that leads into the Waterfront shopping mall which separates the mall from the community of Homestead. Engineers and analysts should consider the spatial distribution of populations and demographic information when deciding where to place a road. Potential uncertainties include the costs and benefits of the construction for the developers and for the community, with or without externalities. Which externalities should be considered?	Model the risk of contamination and probability of health impacts on community based on demographic and available information. Give higher weight to life-threatening and deteriorating risks and include economic costs beyond the initial project including potential healthcare costs, risks, and loss of reputation. Loss aversion would be a better tactic to influence decision makers rather than potential reduced profits in the short term. Propose solutions both upstream and downstream of varying capital costs that mitigate these risks and model a communications strategy that would show a lower litigation risk with increased transparency and true accountability of the issues. It is better to come out front with addressing the issue rather than have a whistleblower or the community engage with the media and damage public opinion.
4	Analyze-draw connections to social justice not mentioned in class; evaluate - support ideas	Flood mitigation plans in urban areas: This is closely related to social justice issues because low-income and minority communities are impacted more by flooding because they are more likely to live in affected areas, have fewer resources to bounce back, and tend to have less political power to advocate for change. Flooding is increasing in certain parts of the	No student reached this level for the unprompted question during the course.

		world due to climate change, so this is also an issue of the uneven distribution of climate change consequences. When making an investment decision about flood mitigation plans, it is important the right model is used so that social inequality can be included. Typically cost-benefit analysis models are used to determine where flood mitigation money is spent. However, this model favors the rich neighborhoods because their property values are often higher. This approach tends to leave the low-income communities without major flood mitigation efforts. Instead, a different model can be used to determine where the flood mitigation money is spent. A social vulnerability index can be incorporated into the model so that those in most need of flood mitigation controls are prioritized.	

Appendix B – Homework 1 Social Justice Assignment

The following group assignment was designed to introduce the students to a diversity issue in engineering, while assessing their estimation abilities. The question was answered in groups of three to four students.

Group question: Complete the task that we started in class - the group estimation problem (from the list of topics your group chose).

Reminder the questions you could choose from were:

- Out of all of the engineers that graduated in 2019, how many were African American? How does this number compare to the total number of people who graduated with engineering degrees?
  - One place to start is https://www.nsf.gov/statistics/2018/nsb20181/report/sections/science-and-engineering-labor-force/women-and-minorities-in-the-s-e-workforce
  - Note that Black is not the same as African American.

- How many Hispanics and African Americans are employed in the energy sector?
  - For this, you may choose one sector (i.e., wind, biomass, solar, coal, etc).
  - One place to start might be the U.S. Energy and Employment Report.
    - https://www.energy.gov/sites/prod/files/2017/01/f34/2017%20US%20Energy%20and%20Jobs%20Report_0.pdf

Please submit the following parts:

a) [5 pts] The question chosen, a summary of the estimation model used, assumptions, and preliminary result from class (done completely without additional data resources).
b) [5 pts] Do some quick research (e.g., using web searches or - gasp! - actual books at the library) and try to collect better data for your estimation. Do not spend more than an hour (total for group) on this search. Feel free to change your model based on data you find. Write a short summary of data sources searched, used, and final data obtained.
c) [3 pts] With your updated model, provide a summary of your new lower bound, best guess, and upper bound range of estimates.
d) [2 pts] What are the consequences of the lack of diversity in the education or energy sector? How might the level of diversity in this sector affect the technologies people are building? How do these numbers compare to the racial breakdown of the U.S. population?

Appendix C – Homework 2 Social Justice Assignment

The following individual assignment was designed to introduce the students to a broad social justice issue that, at first, does not appear to be linked to engineering, while assessing their information design abilities. The question was answered individually.

Question: There have been an increasing amount of wildfires in the western U.S. (see: 3 and 4 in the additional data below). To help combat these fires, states have been hiring inmates to do this dangerous work (sometimes only paying them $1 an hour). Additionally, in the U.S., some companies have used prisoners to produce many of the things we use every day. Some of these items include mattresses, car parts, and stop signs. First, please read this short web article, which summarizes issues related to mass incarceration in the U.S. https://www.prisonpolicy.org/reports/pie2020.html

In the U.S., the abolition of slavery (the 13th amendment) applied to everyone except those convicted of crimes (i.e., prison inmates). In short, there are many economic things that lead to mass incarceration as a problem in the U.S.

Based on our lecture on information design and considering it has been two years since the article:

a) [2 pts, short answer] Using terms from lecture, describe the various flaws or good things you perceive in the presentation of the statistical graphics and conclusions in the web article.

b) [3 pts, short answer] Summarize the key "messages" that should be in a graphic pertaining to mass incarceration in the U.S.

c) [4 pts] Of the people in **local jails,** what percent of them are convicted of a violent crime? Create a graphic that illustrates this and provide a short summary (less than 60 words).

d) [7 pts] Design and submit an alternative graphic and short summary (less than 60 words) that more clearly conveys the message of one of the pie charts detailing the issue of mass incarceration in the U.S. This must be different from the one mentioned in part C.

e) [2 pts, short answer] – Who do you think is the most impacted by this mass incarceration problem? How are mass incarceration and climate change linked? This can be linked to our climate change mitigation and adaptation plans. Can anything from class be used to help solve the problem of mass incarceration?

Appendix D – Homework 3 Technical and Social Justice Assignment

The students completed Homework 3 individually. The students in Treatment A received the following questions:

Question 1: A car company builds vehicles for disabled populations. These vans allow people who have lost limbs to drive and experience the independence that comes with increased mobility. One challenge is that the cars are very expensive, and they want to increase the amount of customers they are able to serve. This company is deciding whether or not to outsource its car manufacturing operations to a local prison. The demand of cars per year for the handicapped accessible vehicles is given by: p = 80,000 – 0.2*q

a) If the company outsources the manufacturing to the local prison population, then the price will be $25,000. This reduced price stems from the low and nonexistent wages the company will have to pay the prisoners. At this price, how many cars can the company expect to sell per year?
b) At a price of $25,000, what is the price elasticity of demand?
c) At a price of $25,000, what are total benefits, user costs, and net user benefits (a.k.a., consumer surplus)?
d) If the car company decides to keep their operations in house, and they expect the price to rise to $50,000, what are changes in: total benefits, user costs, and net user benefits?
e) What do you think the company should do? Why?
f) When making this decision, what individuals or groups of individuals should be considered or asked to provide input?

Question 2: In 2019, the world produced 4.4 billion tons of concrete annually, but that number is expected to rise to over 5.5 billion tons by 2050 as poorer countries rapidly urbanize. Over time, concrete has become popular due to it being a building material that is resilient to weather, its versatility, low maintenance costs, and durability. Concrete lasts decades longer than alternative building materials. This reduces the total cost of ownership as well as the environmental impact associated with more frequent rehabilitation or reconstruction. Consider a firm that sells bags of concrete with a linear supply function producing in market equilibrium. At this equilibrium, the price elasticity of supply is 1.5, the price of the good equals $30, and the quantity equals 10 units.

a) What is the equation for the supply curve?
b) Calculate the producer surplus in the market.
c) If a policy causes the price to fall to $20, what is the change in producer surplus?
d) What fraction of the changed producer surplus is due to the change in price per unit sold, and what fraction is due to the change in quantity? Explain your reasoning.
e) If the tax does not come through, then the company could use slightly cheaper components (i.e., cheaper gravel and no rebar) to reduce the cost from $30 to $20. These cheaper materials

would also reduce the expected lifetime of their concrete from 12 years to 7 years. What do you think the company should do? Why?

f) When making this decision, what individuals or groups of individuals should be considered or asked to provide input?

The students in Treatment B received the following questions:

Question 1: Toll roads are often used to cover the maintenance costs of different infrastructure projects like federal highways and bridges. The demand of trips per hour on a toll road is given by: $p = 30 – 0.2*q$

a) If the price is $10, how many trips will be taken per hour?
b) [2 pt] At a price of $10, what is the price elasticity of demand?
c) At a price of $10, what are total benefits, user costs, and net user benefits (a.k.a., consumer surplus)?
d) If price rises to $12, what are changes in: total benefits, user costs, and net user benefits?
e) Do you think the tolls should be risen? Why?
f) When making this decision, what individuals or groups of individuals should be considered or asked to provide input?

Question 2: Across the world, LGBTQ youth risk being rejected by their families when "coming out" (i.e., revealing their identity within the LGBTQ community). Unfortunately, LGBTQ youth who have been rejected and kicked out of their homes by their biological families are more likely to enter the juvenile prison system or risk harm due to the higher rate of homelessness. Firm A builds tiny homes in Louisiana. The main users of these homes are LGBTQ youth who have been kicked out of the homes of their biological families. Assume the firm has a linear supply function producing in market equilibrium. At this equilibrium, the price elasticity of supply is 1.5, the price of the good equals $3,000, and the quantity equals 10,000 units.

a) What is the equation for the supply curve?
b) Calculate the producer surplus in the market.
c) If a government tax policy causes the company's selling price to fall to $2,000, what is the change in producer surplus?
d) What fraction of the changed producer surplus is due to the change in price per unit sold, and what fraction is due to the change in quantity? Explain your reasoning.
e) If the tax policy does not take effect, then the company could outsource to the local prison population to reduce the cost of manufacturing the homes and lead to a selling price of 2,000. What do you think the company should do? Why?
f) When making this decision, what individuals or groups of individuals should be considered or asked to provide input?

Appendix E – Homework 4 Technical and Social Justice Assignment

The students completed Homework 4 individually. The students in group A received the following questions:

Question 1: According to the National Highway Safety Administration, the probability that a teen-aged driver in the U.S. will have an accident in a six-month period is 30%. Assume a U.S. teenager has a car with a value of $6,600 and is considering purchasing insurance for the car. She has learned that the six-month premium amount for insurance with a $500 deductible[1] is $1,250. She is not sure that she can afford that much, so she decides to investigate the cost of insurance with $1,000 deductible. The six-month premium for insurance with a $1,000 deductible is $1,050. She is also considering the possibility of not carrying any insurance.

Further assume that if she does have an accident, Table 1 shows the probabilities of 4 damage categories. Midpoint damage ranges have been assumed for each category except the worst-case damage category, which is "total" damage, equal to the full value of the car.

Table 1: Probabilities of accident types and estimated damages

Probability	Damage Range	Assumed Damage
0.45	Less than or equal to $500	$250
0.15	$500 to $1,000	$750
0.25	$1,000 to Half Value	$2,150
0.15	Half Value to Total Value	$6,600

a) Do you think it is right for insurance companies to charge teenagers more for their insurance?
b) What are the expected costs of each insurance option (including no insurance)? Which option should she choose if she is risk-neutral?
c) Which option should she choose with an exponential utility function, R=1000?
d) Which option should she choose with an exponential utility function, R=50000?
e) For a risk neutral decision maker, how does the decision of which option to choose change as the probability of having an accident varies (from 0 to 100%)? Find a clear and useful way of displaying this result.

[1] If you are not familiar with deductibles, a simple definition of a deductible is the amount you need to first pay before the insurance pays any of the damage costs (feel free to look at other references for more detail). For example, if you have an accident that causes $5,000 damages with a $1,000 deductible policy, you pay $1,000, and the insurance company pays the remaining $4000.

f) For a risk neutral decision maker, is the EVPI additive for knowing both the chance of the accident and the amount of damage?
g) For a risk neutral decision maker, how does your decision of which option to choose change as the probability of having an accident AND the cost of the $1000 deductible policy both vary? Find a clear and useful way of displaying this result.
h) What if insurance is required? How does that change your answer from part A?
i) The data above assumed relatively low damages (presumably because the cars teen-aged drivers drive are old). How would your decision change if the probability of having an accident varies, AND the total value of the car varies from $3,000 up to $20,000? Find a clear and useful way of displaying this result.

Question 2 – Please keep answer for question 4 less than 3 pages.

As we move toward the future and experience the effects of climate change, nations are trying to reduce the CO2 emissions associated with their energy systems. Power systems are a large contributor to global CO2 emissions. A key social justice concern here is that the higher CO2 emission power plants are often in low income and minority areas. This can lead to more asthma cases and health risks in these communities. When decision makers are trying to shift their power systems, they need to consider the base line for the current level of CO2 emissions and make the best decision for which technology mix to invest in.

a) The following data is for electricity planning options in a region in the U.S. using seven different types of power plants (wind, solar, nuclear, hydro, coal and oil). Electricity production is in GWh/year, and generation costs in $/year (and are independent of each other). Assume that because of the health concerns in low-income areas, the region will start charging $0.02/gCO2. By causing the costs of systems with high CO2 production to rise, the region is hoping to push power plants to retire and reduce asthma and childhood mortality. If electricity market prices are expected to be $0.05/kWh and gross electricity revenues are production times price, do any of the alternatives dominate the others in terms of expected profit, given only this data?

Alternative	**Avg Production (GWh)**	**Avg Costs ($)**	**Expected CO2 Emissions (gCO2 eq)**
1 – High Oil and Coal	3.5	200	500
2 – High Wind	3.5	243	300
3 – High Solar	3.5	260	200
4 – High Oil	3.5	300	1000
5- High Coal	2	195	900

6 – High Nuclear	2	180	300

b) Now assume that the table below shows the **triangular** distributions of production for the six alternatives. Also assume that:

- Generation costs are **uniform** with lower and upper values of ± 20% of the costs given above.
- CO2 emissions for each alternative vary by ± 10% for the CO2 emissions given above.

Which one would you now recommend in terms of expected profit and why? Be sure to show your result graphically.

Alternative	Min Production	Mode Production	Max Production
1	2.2	3.5	5.8
2	2.2	3.5	5.5
3	1.5	3.5	5.8
4	1.5	3.5	5.3
5	1.3	2	3
6	1.1	2	3

c) Due to a government policy to remove illegal immigrants from the region, energy developers are concerned about the resulting increased labor costs in construction of these projects. This policy could mean that the number of construction workers and miners would increase due to having to contract labor unions of U.S.-based workers. Due to the high costs, the alternative 1 has become infeasible. There is also another concern over public health and a push to reduce CO2 emissions, leading to the government moving away from 4 and 5. Would your recommendations from parts B and C change?

Students in group B received the following homework questions to be completed individually:

Question 1: Insurance company A provides different pricing strategies based on demographics. Erica is a teenage driver with a disability. She suffers from seizures, which can cause trouble when driving. According to the National Highway Safety Administration, the probability that a teen-aged driver in the U.S. will have an accident in a six-month period is 30%. Assume Erica is a U.S. teenager who lives in a food desert and low-income area. This car is essential because she currently spends two hours on the bus to go to the grocery store. Assume she has a car with value of $6,200 and is considering purchasing insurance for the car. She has learned that the six-month premium amount for insurance with a $500

deductible[2] is $1,250. She is not sure that she can afford that much, so she decides to investigate the cost of insurance with $1,000 deductible. The six-month premium for insurance with a $1,000 deductible is $1,050. She is also considering the possibility of not carrying any insurance. Not carrying insurance could be a big risk since she suffers from seizures and might black out while driving. She is concerned that upon the insurance realizing she has a disability they will raise all of her premiums due to her increased risk.

Further assume that if she does have an accident, Table 1 shows the probabilities of 4 damage categories. Midpoint damage ranges have been assumed for each category except the worst-case damage category, which is "total" damage, equal to the full value of the car.

Table 1: Probabilities of accident types and estimated damages

Probability	Damage Range	Assumed Damage
0.45	Less than or equal to $500	$150
0.15	$500 to $1,000	$750
0.25	$1,000 to Half Value	$2,100
0.15	Half Value to Total Value	$6,200

a) Do you think it is fair for insurance companies to charge people with disabilities more for their insurance? How might this impact someone like Erica who lives in a food desert and has a disability?
b) What are the expected costs of each insurance option (including no insurance)? Which option should she choose if she is risk-neutral?
c) Which option should she choose with an exponential utility function, R=1000?
d) Which option should she choose with an exponential utility function, R=50000?
e) For a risk neutral decision maker, how does the decision of which option to choose change as the probability of having an accident varies (from 0 to 100%)? Find a clear and useful way of displaying this result.
f) For a risk neutral decision maker, is the EVPI additive for knowing both the chance of the accident and the amount of damage?
g) For a risk neutral decision maker, how does your decision of which option to choose change as the probability of having an accident AND the cost of the $1000 deductible policy both vary? Find a clear and useful way of displaying this result.
h) Now assume Erica has no choice due to the insurance company requiring those with a disability to obtain insurance. How does that change your answer from part A?
i) The data above assumed relatively low damages (presumably because the cars teen-aged drivers drive are old). How would your decision change if the probability of having an accident varies, AND the total value of the car varies from $3,500 up to $25,000? Find a clear and useful way of displaying this result.

Question 2 – Please keep answer for question 4 less than 3 pages.

a) The following data is for electricity planning options in the U.S. using seven different types of power plants (wind, solar, nuclear, hydro, coal and oil). Electricity production is in GWh/year and generation costs in $/year (and are independent of each other). If electricity market prices are expected to be $0.05/kWh and gross electricity revenues are production times price, do any of the alternatives dominate the others in terms of expected profit given only this data?

Alternative	Avg Production (GWh)	Avg Costs ($)	Avg tax that must be paid to government ($/GWh)
1 – High Oil and Coal	3.5	230	10
2 – High Wind	3.5	241	5
3 – High Solar	3.5	260	9
4 – High Oil	3.5	256	12
5- High Coal	2	165	9
6 – High Nuclear	2	157	5

b) Now assume that the table below shows the **triangular** distributions of production for the six alternatives. Also assume that:

- Generation costs are **uniform** with lower and upper values of +- 20% of the costs given above.
- Electricity market prices will vary uniformly between 0.02 and 0.10 $/kWh.

Which one would you now recommend in terms of expected profit and why? Be sure to show your result graphically.

Alternative	Min Production	Mode Production	Max Production
1	2	3.5	5.5
2	2	3.5	5
3	1.7	3.5	5.5
4	1.7	3.5	5
5	1.5	2	2.7
6	1.2	2	2.7

c) Due to a government policy to remove illegal immigrants from the region, energy developers are concerned about the resulting increased labor costs in construction of these projects. This policy could mean that the number of construction workers and miners would increase due to having to contract labor unions of U.S.-based workers. Due to the high costs, the alternative 1 has become infeasible. There is also another concern over public health and a push to reduce CO2 emissions, leading to the government moving away from 4 and 5. Would your recommendations from parts B and C change?

Appendix F – Distribution of Homework Scores

The homework scores for Fall 2020 and Fall 2021 for Homeworks 3 and 4 are shown in Figures F1 and F2. We see a wider distribution of scores in the economics social justice question earlier in the semester (Homework 3) and a narrower distribution of the scores, across all questions, later in the semester (Homework 4). In general, all of the students are scoring higher on the homework questions regardless of social justice or technical framing by the end of the semester.

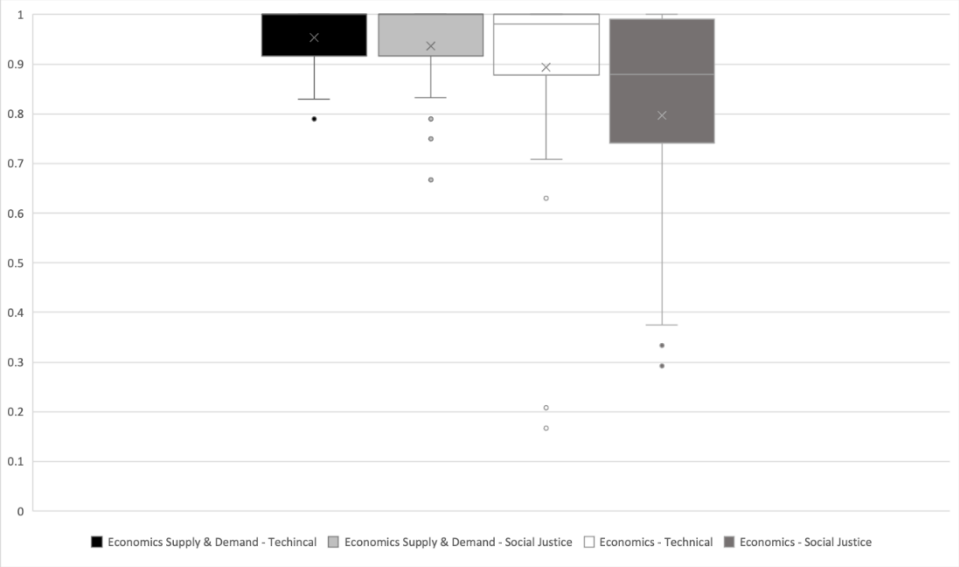

Figure F1: Homework 3 distribution of scores across the technical and social justice problems.

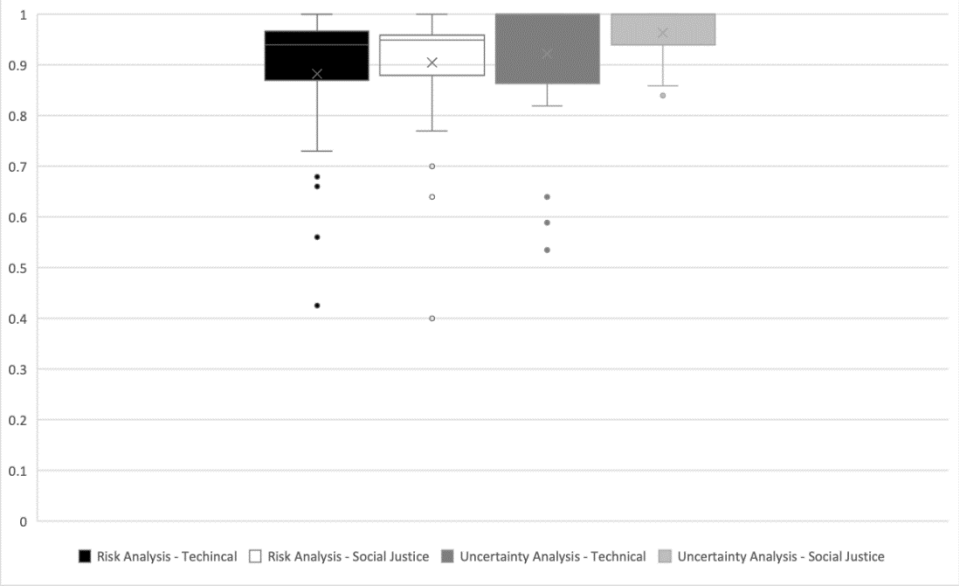

Figure F2: Homework 4 distribution of scores across the technical and social justice problems.