Discussion of Project #1

Task 1 and 2

1. When density is set to a constant, the system considered in this project is a rather inefficient heater with only a small gain in temperature as water flows through the tank. In the majority of the submissions, the difference in temperature between outlet and inlet falls within the range of 2.5-7.5°C. When the buoyancy effect is suppressed by holding density constant, the cold water stream that comes through the inlet just keeps moving forward instead of sinking. The warm water at bottom does not rise by positive buoyancy, either. In this case, little cold water can reach the bottom of the tank. Note that having cold water reaching the bottom is key to maintaining a sharp vertical temperature gradient at the bottom boundary, which would sustain a strong heat flux from the bottom plate into the tank. In a steady state, this flux essentially determines the temperature difference between the outlet and inlet.

2. In reality, over the range of temperature of our interest, density of water decreases with temperature. If this effect is taken into account (as is the case in **Challenge #5**), buoyancy effect would allow the cold water to sink as it enters the tank. Likewise, the warm water at bottom would rise by thermal convection. This will significantly increase the outlet temperature. We will have more detail on this point in the coming discussion for Challenge #5.

3. The group with Z_1 = 1.0 m generally produce the lowest outlet temperature while the group with Z_1 = 0.2 m produce the highest temperature. In the absence of buoyancy effect, the set up of Z_1 = 0.2 m at least allows cold water to reach closer to the bottom. Interestingly, among the 3 cases in the group with Z_1 = 0.2 m, the case with Z_2 = 0.2 m is not the most favorable for producing warm water at the outlet. An examination of the flow pattern indicates that in this case a large portion of the cold water flows directly from inlet to outlet. At near the bottom, the mass flux of the (cold) water flow for this case is actually weaker than the cases with Z_2 = 0.6 and 1.0 m. These last two cases generally produce the highest outlet temperature. The difference between the two cases is small enough that we don't have a clear-cut interpretation for the slightly better performance by the case with Z_2 = 1.0 m.

4. Because the differences among the 9 cases are not large, the detailed order is sensitive to the setup of Fluent. Some of the factors that could contribute to the differences are: (i) Mesh resolution; (ii) The chosen numerical schemes (1st vs. 2nd order, etc.); (iii) The number of iterations performed. One of the common deficiencies of the reports is the lack of information on those details that would have affected the outcome of simulation. If those details were provided in the reports, we could have done a statistical analysis to help explain the variance of the results of the simulations produced by different students.

5. Despite the sensitivity described in (4), some features in the simulations are robust. We illustrate this by compiling the statistics of the number of students who report a certain case as the one with the highest outlet temperature:

		Z_1		
		0.2 m	0.6 m	1.0 m
Z_2	0.2 m	12	2	1
	0.6 m	21	0	0
	1.0 m	**48**	0	0

Another statistics of the number of students who report a certain case as the one with the lowest outlet temperature:

		Z_1		
		0.2 m	0.6 m	1.0 m
Z_2	0.2 m	0	0	1
	0.6 m	0	0	12
	1.0 m	0	2	**68**

Based on the statistics, we do have a clear consensus after all.

Task 3

The temperature at outlet should increase with a decreasing inlet velocity. We have explained this point in previous lectures.

Task 4

The majority of the submissions reported that the "turbulence" case produces a slightly higher (by 1-2C at most) outlet temperature than the "laminar" case. This is reasonable since with the turbulence model there is an additional mechanism of turbulent (eddy) heat transport which can help move heat around more efficiently. Nevertheless, with the buoyancy effect turned off, the impact of this extra term is somewhat muted. There are also reports of difficulties to make the "laminar" case converge to a steady state. This is not unexpected. We have discussed the point in previous lectures.

Task 5

If the condition of constant heat flux is imposed correctly, we should recover the outlet temperature from the simulation with constant temperature at bottom. This can be understood by an argument of total heat balance, as we have discussed in previous lectures.