Q1: There is a whole scientific community interested in providing an indisputable proof that nature violates Bell's inequality. Explain why the Big Bell Test assures that they closed all the loopholes and what does it imply for our understanding of the universe.

C1: Defined the concept of loophole in Bell's inequality context. Described the freedom of choice loophole. Summarized the arguments of the Big Bell Test collaboration about why they are closing the freedom of choice loophole.

A1: Bell Test requires certain conditions, one of which is having unpredictable measurement settings. In terms of Bell's inequality, statistical independence of choices from the hidden variables that describe possible measurement outcomes is required. This independence can fail in different ways, one of which is named Freedom of Choice Loophole (FOCL). FOCL considers the possibility in which hidden variables lambda influence the setting choices. This freedom of choice cannot be guaranteed by the use of physical devices and laboratory methods (the loophole can be tightened but not fully closed). For that purpose BBT uses human choices, relying on the fact that free will is inherently random and no hidden variables govern those (as unlike electrons/protons/Higgs boson, which are interchangeable particles and behave alike under the same conditions, every human being acts independently). Moreover, they enforce the unpredictability aspect by certain gaming constraints. BBT also tightens the locality loophole by using numerous independent experiments instead of space separation. The organizers of BBT claim that the latter argument alongside with the human capacity for free choice remove the need for assumptions concerning physical indeterminism. Regarding our understanding of the universe, the results of BBT show disagreement with the theory of local realism in the context of various physical systems and scenarios.

Q2: Gamification is a powerful tool that can be used in several contexts, such as marketing and generation of products. Explain how The Big Bell Test experiment utilized gamification for generating random numbers and imagine and discuss other possible applications of gamification in quantum computing.

C2: Described how the Big Bell Test Game works. Explained the process done by the Big Bell Test collaboration for generating random numbers. Gave one possible application of gamification in quantum computing.

A2: The BBT Game consists of several levels, in which the participant should enter a sequence of zeros and ones as random as possible in a limited time frame. At each level participants are presented with a challenge-reward-like structure, where the challenge is to produce random choices (which are later encoded as bits and sent to the experiment nodes), while avoiding being predicted by the Oracle. The game features various mechanics such as boss levels, power ups, timers and etc. Animation and sound-effects are incorporated to boost engagement. As the main aim of the game is to collect a high-rate sustained input of unpredictable bits, players are rewarded based on the level of randomness produced. For that purpose, the unpredictability of the input is benchmarked by an ML algorithm (Markov model) and the respective score is assigned, so that the player is incentivized to generate more random bits. Leaderboards and shareability aspects are there to attract more players and encourage more trials.
As for the applications of gamification in quantum computing, one can use modern game mechanics for teaching QC. For example, by creating puzzles/dungeons in which the players need to use certain gates to get correct results and beat the level/boss. The interactivity component can help players better understand the underlying concepts and the level-based mechanic with rewards can further incentivize the replayability.

Q3: Choose two of the thirteen nodes of the Big Bell Test experiment and compare their physical system, degree of freedom measured, rate of bits consumed and total number of bits, how where the bits used, how long the experiment took, and the distance between Alice and Bob.

C3: Compared the physical system and degree of freedom that each node used, and also compared the rate of bits consumed and total number of bits. Described how bits were used, how long the experiment took and the distance between Alice and Bob.

A3: The chosen nodes are the NIST Boulder (NB, 13) and Buenos Aires (BA, 11). Both nodes used photon pairs created from a single input photon created by using the method of parametric downconversion. Similarly, both nodes measured the polarization degree of freedom of the photons. The BA lab performed the experiment live with a bitrate of 1.02 bits per second, using 33,920 total bits in the whole experiment. On the contrary, the people at NB node did not perform the experiment live but instead collected 81,119,980 bits (2500 times more than in the case of the BA node), then ran the experiment at a rate of 100,000 trials per second, and consumed the bits at a rate of 200,000 bits per second. Moreover, they also used high-efficiency detection to avoid the assumption of fair sampling, thus closing not only the FOCL but also the detection efficiency loophole. The BA node targeted the S value of the inequality, whereas the NB node obtained values for J, both resulting in the violation of the inequality. Regarding the use of the bits, the people at the BA lab used theirs to rotate two half-waveplates, whose orientation angle rotated the polarization axis of the incoming photon. Those combined with a polarizing beam acted as a projector of polarization (i.e., as the choice of the measurement basis). The NB node also dealt with polarization, however, they used the bits provided by the Bellsters as the alternative to Alice's/Bob's decisions on how to set the devices known as Pockel cells. Those are later combined with polarizers to rotate to a given position, similar to the Buenos-Aires node. The two nodes differed significantly in terms of the length of the experiment: while it took nine hours for BA node, the experiment at NB took only 7 minutes to run. This can be attributed to the fact that the data collection was not in realtime in the latter case. The distances between Alice and Bob also differed significantly: at BA the distance between Alice and Bob setups was approximately 3.5 meters, whereas at NB they were set 187 meters apart (53 times further).