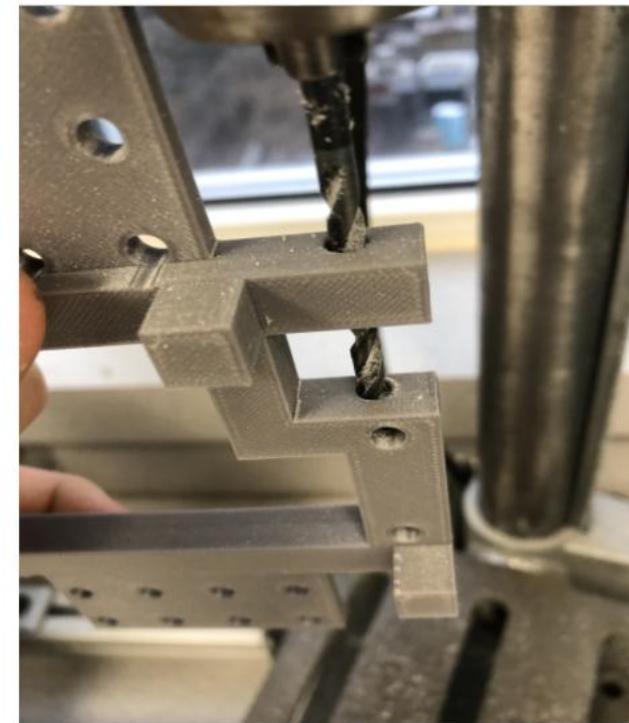
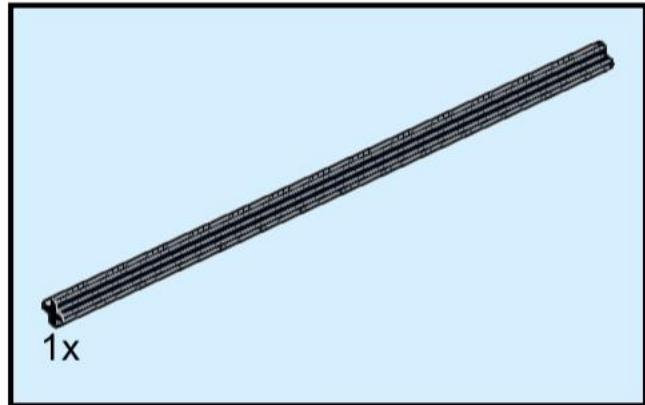


# LEGOLAS Trolley Instructions



After 3D printing the Cart Base, the axle holes will not be perfectly cylindrical, so use a 3/16" or 5 mm drill bit on a drill press to bore out any remaining support material. Do this for both the powered and unpowered axle holes. Check that enough material is removed by inserting a Technic, 12L axle and ensuring that it can rotate freely

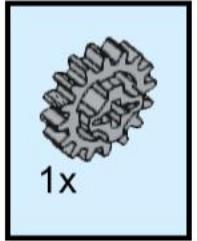
**1**



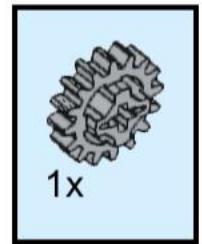
**1x**



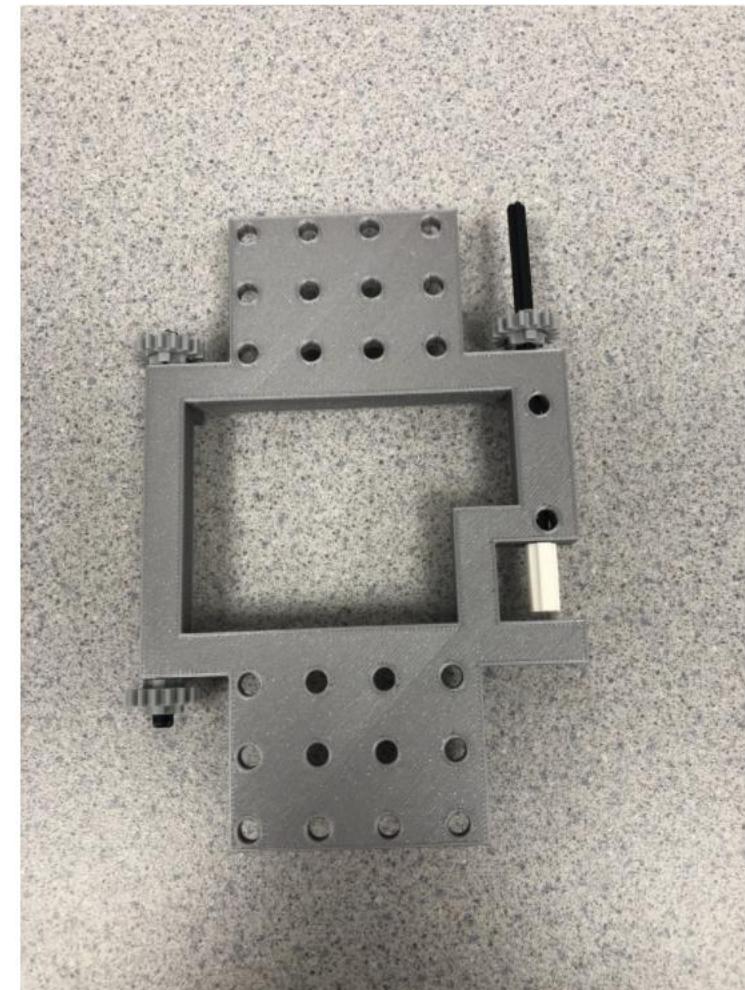
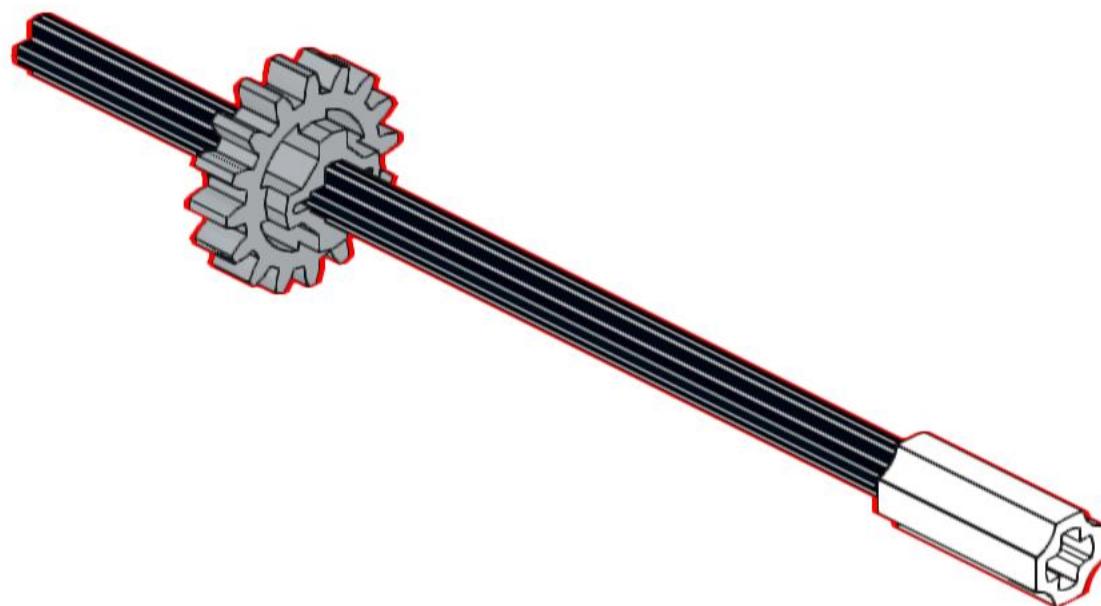
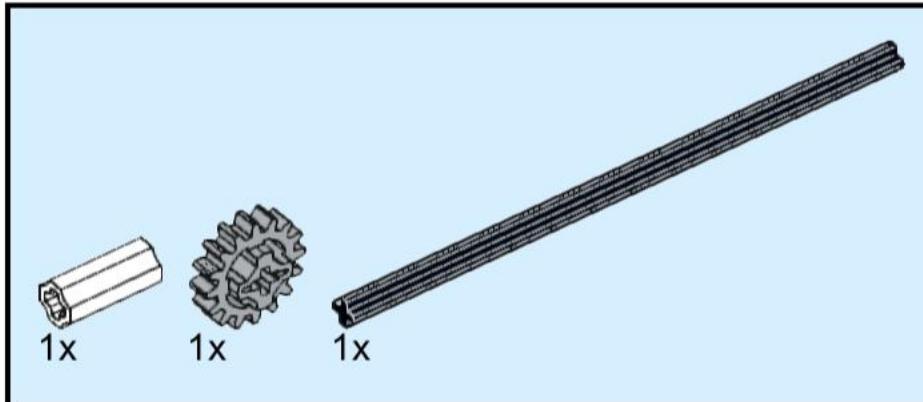
**2**



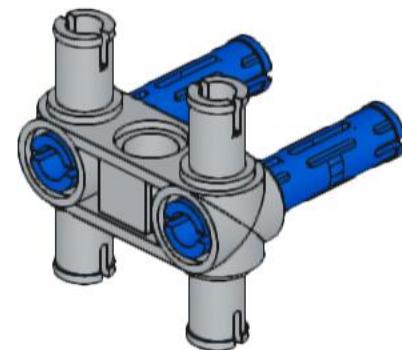
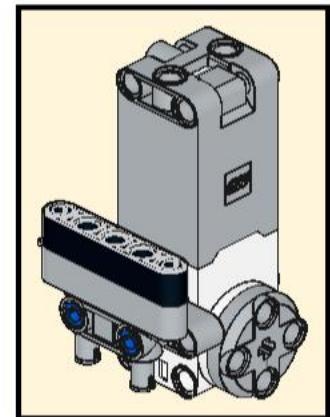
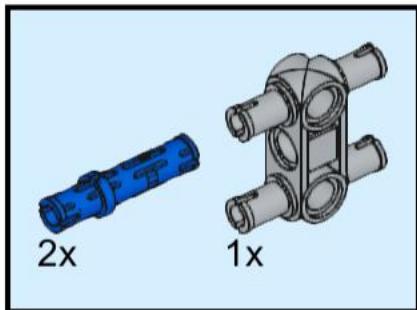
**3**



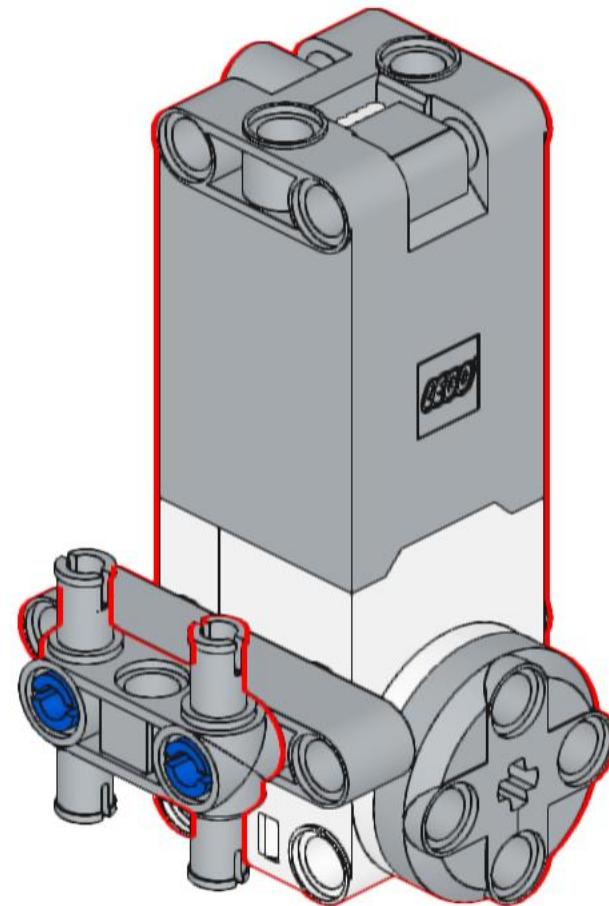
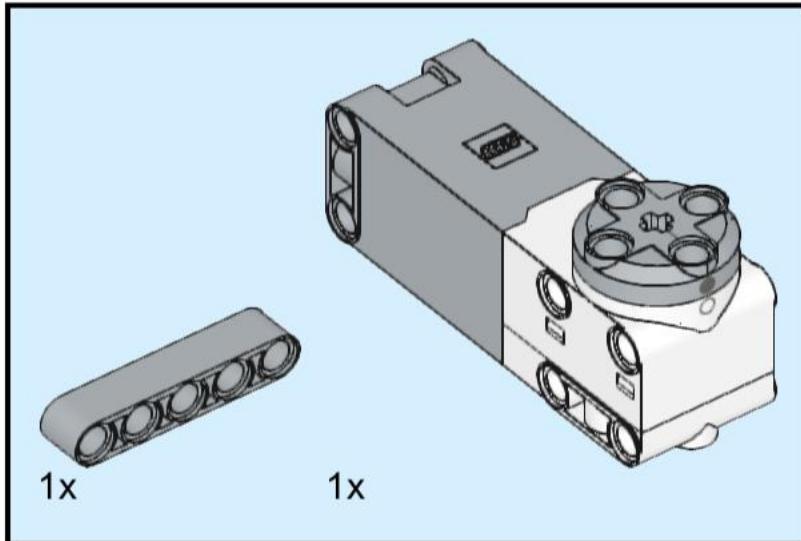
**4**



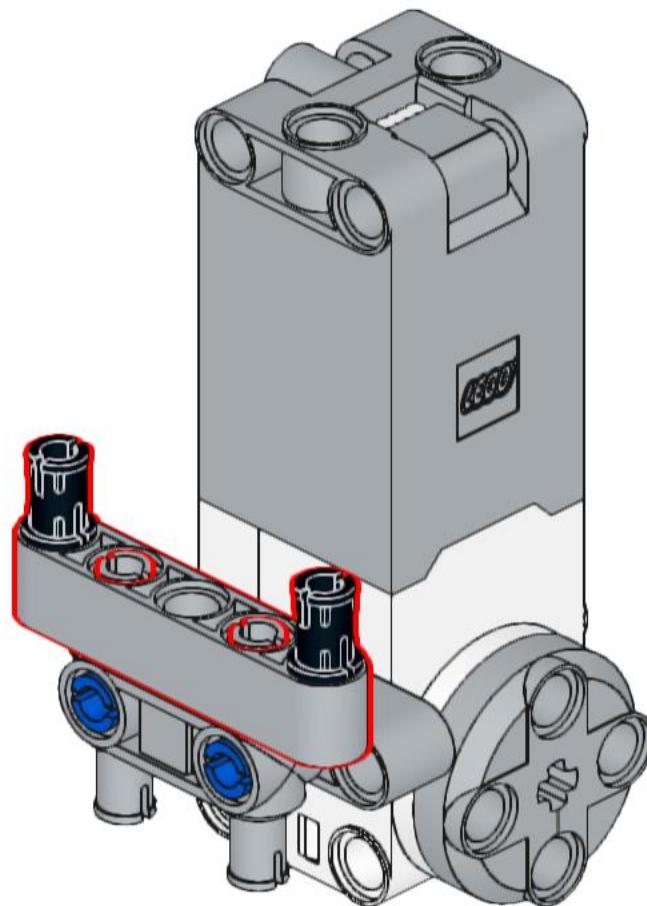
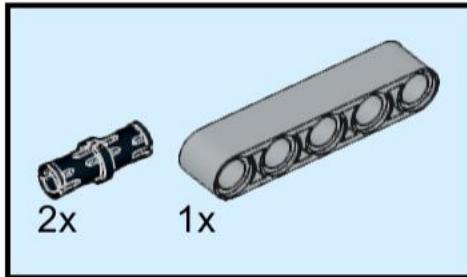
**5**



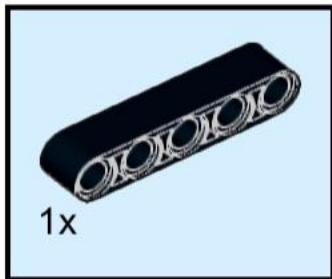
**6**



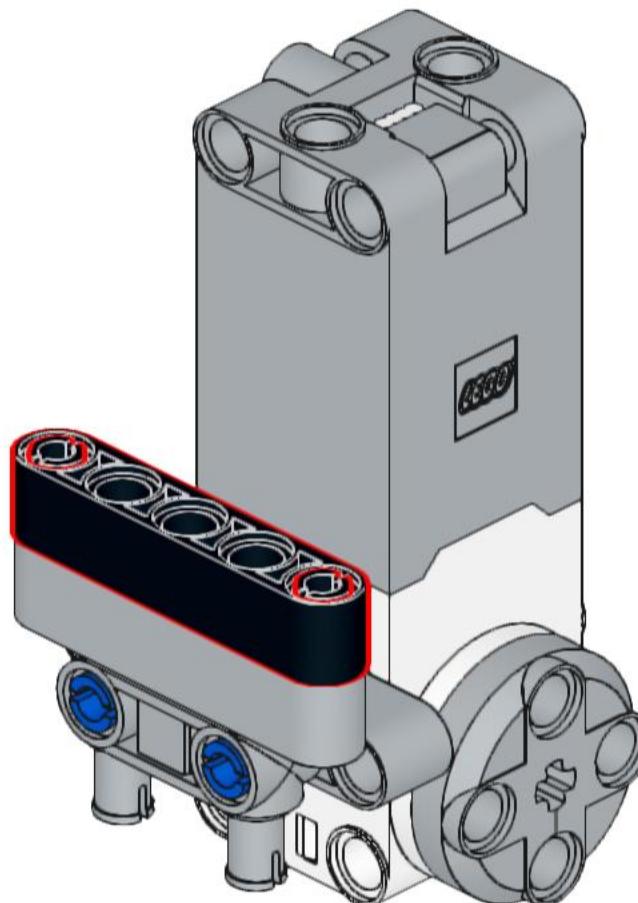
7



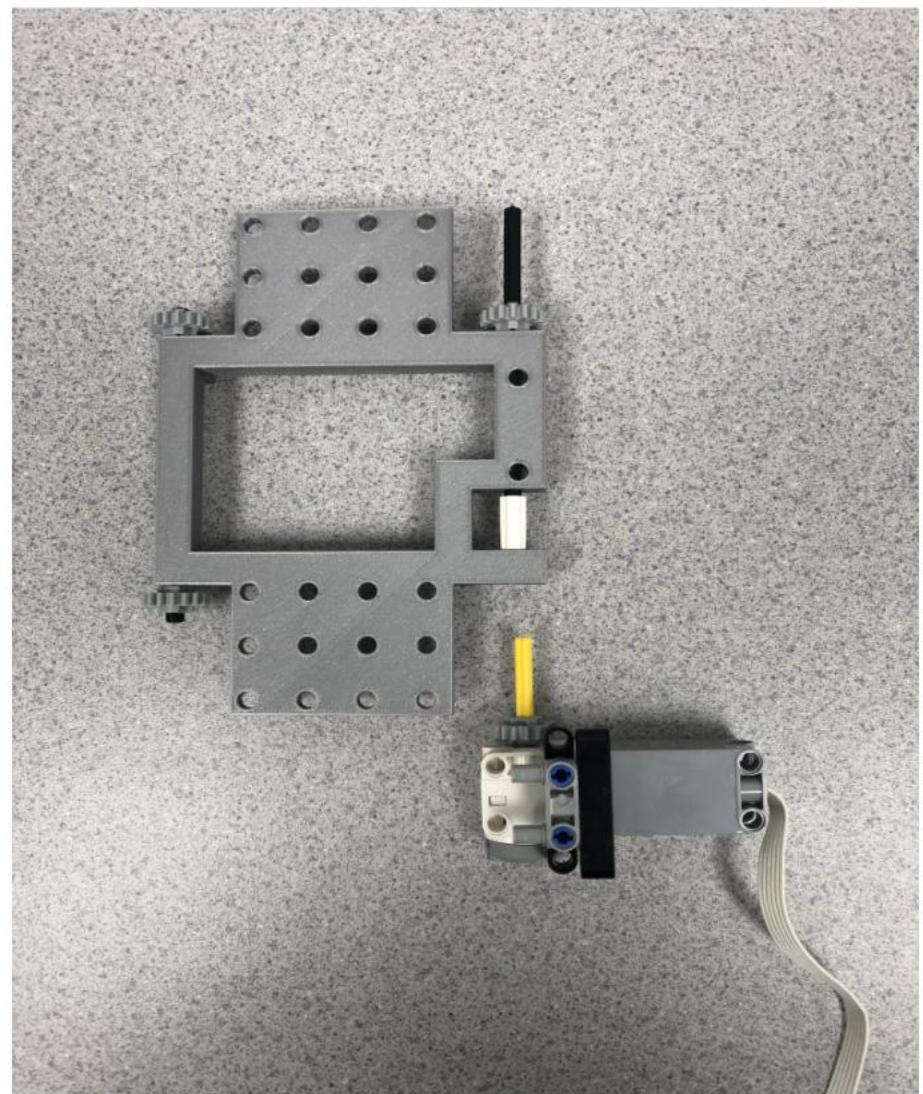
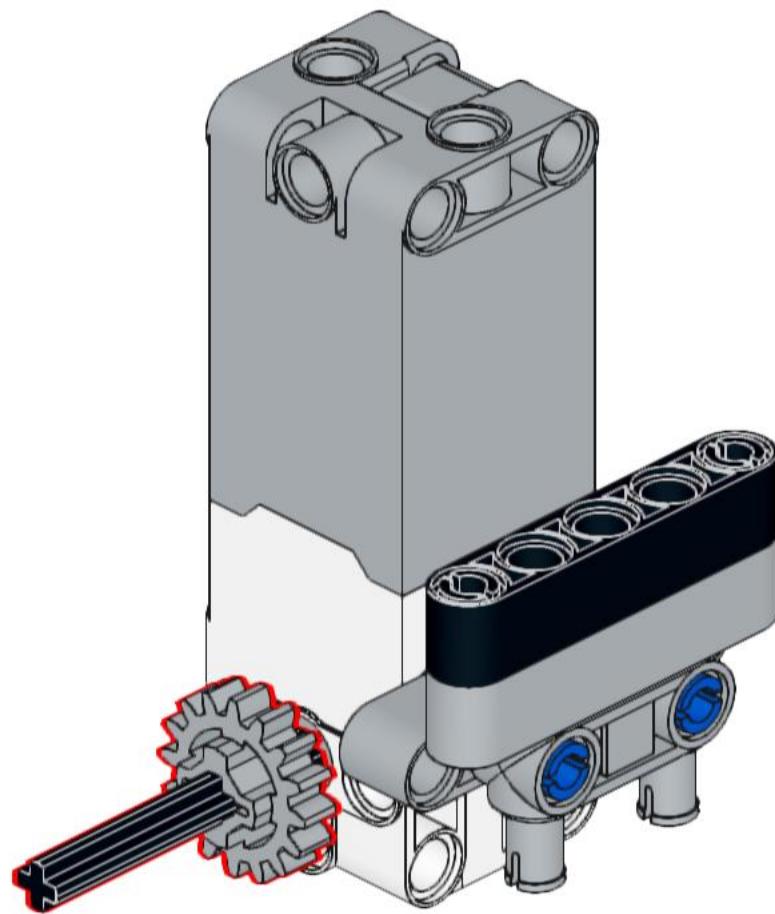
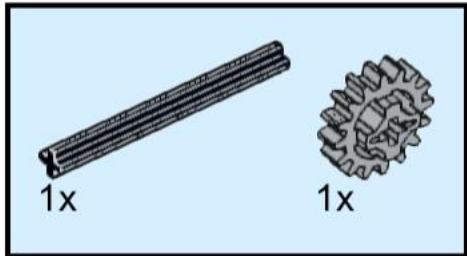
8



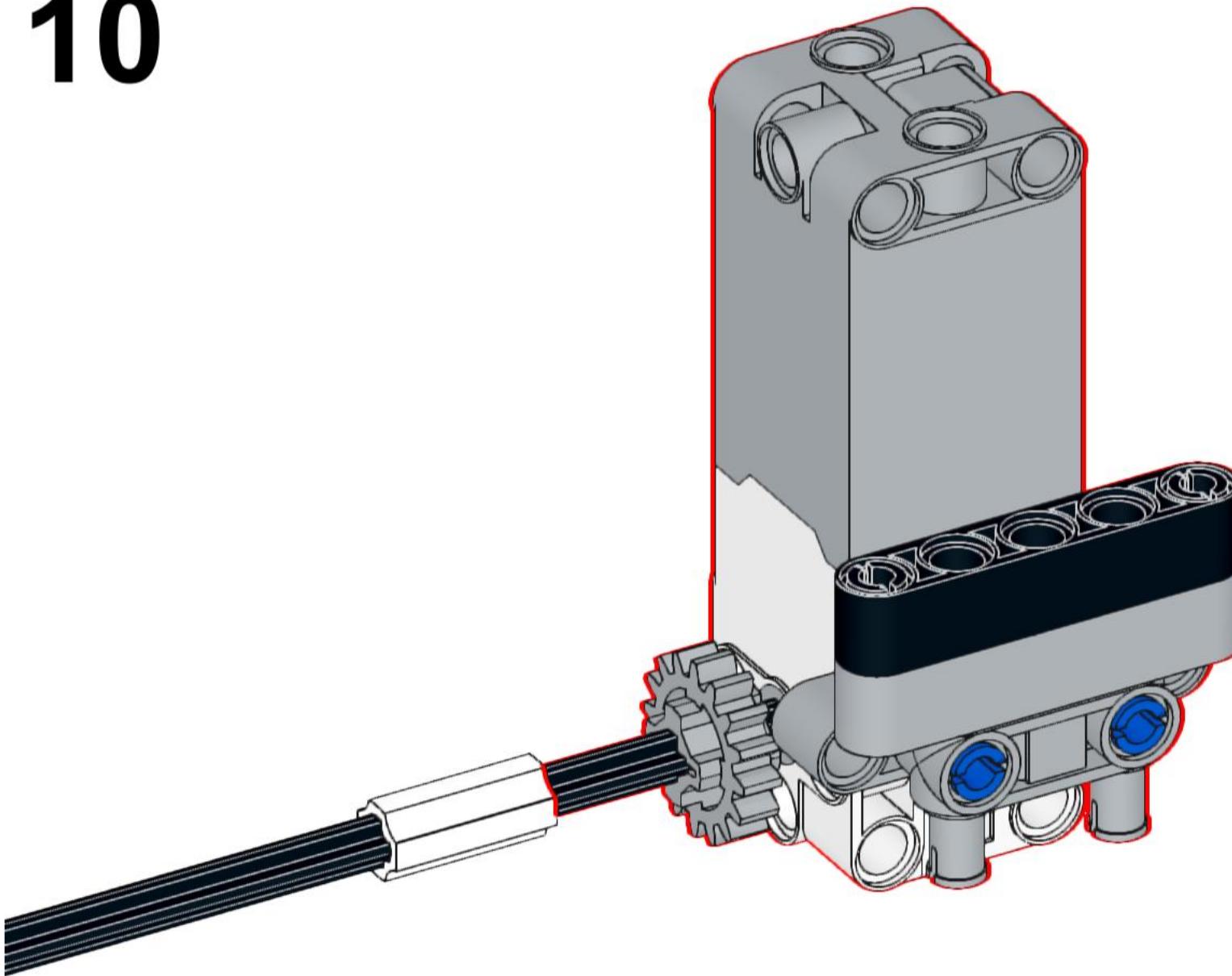
1x



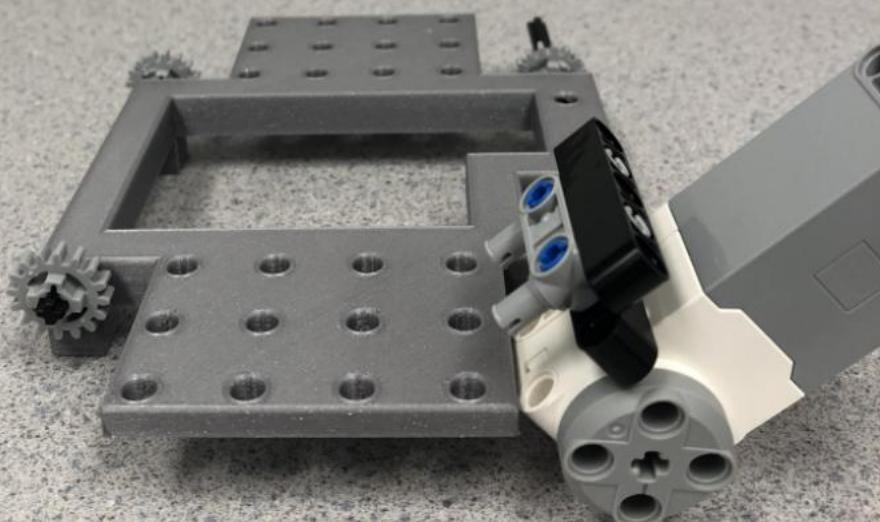
**9**



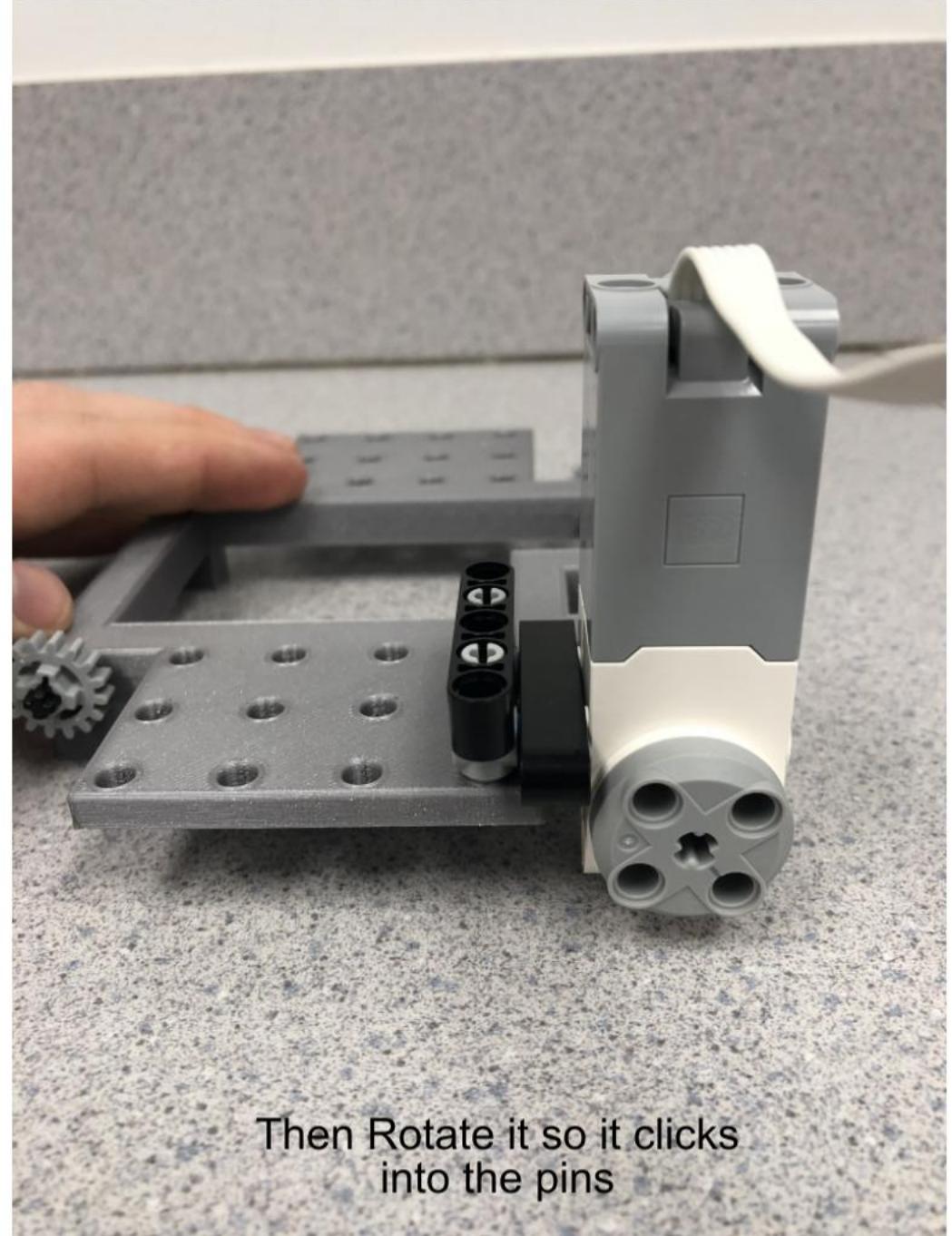
# 10



See next  
page for  
special  
installation  
instructions

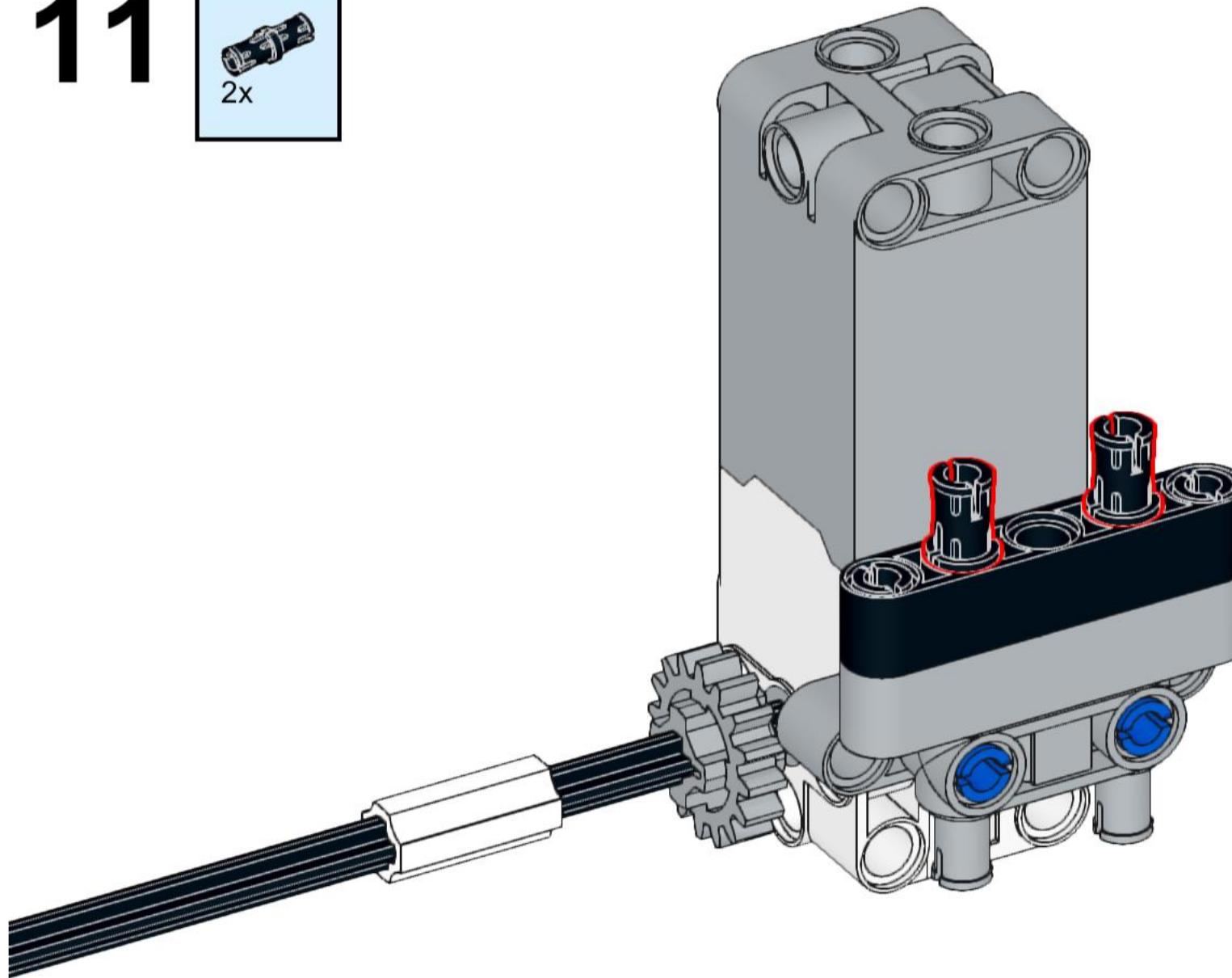


First Insert the Powered  
Motor Assembly at an  
angle into the axle

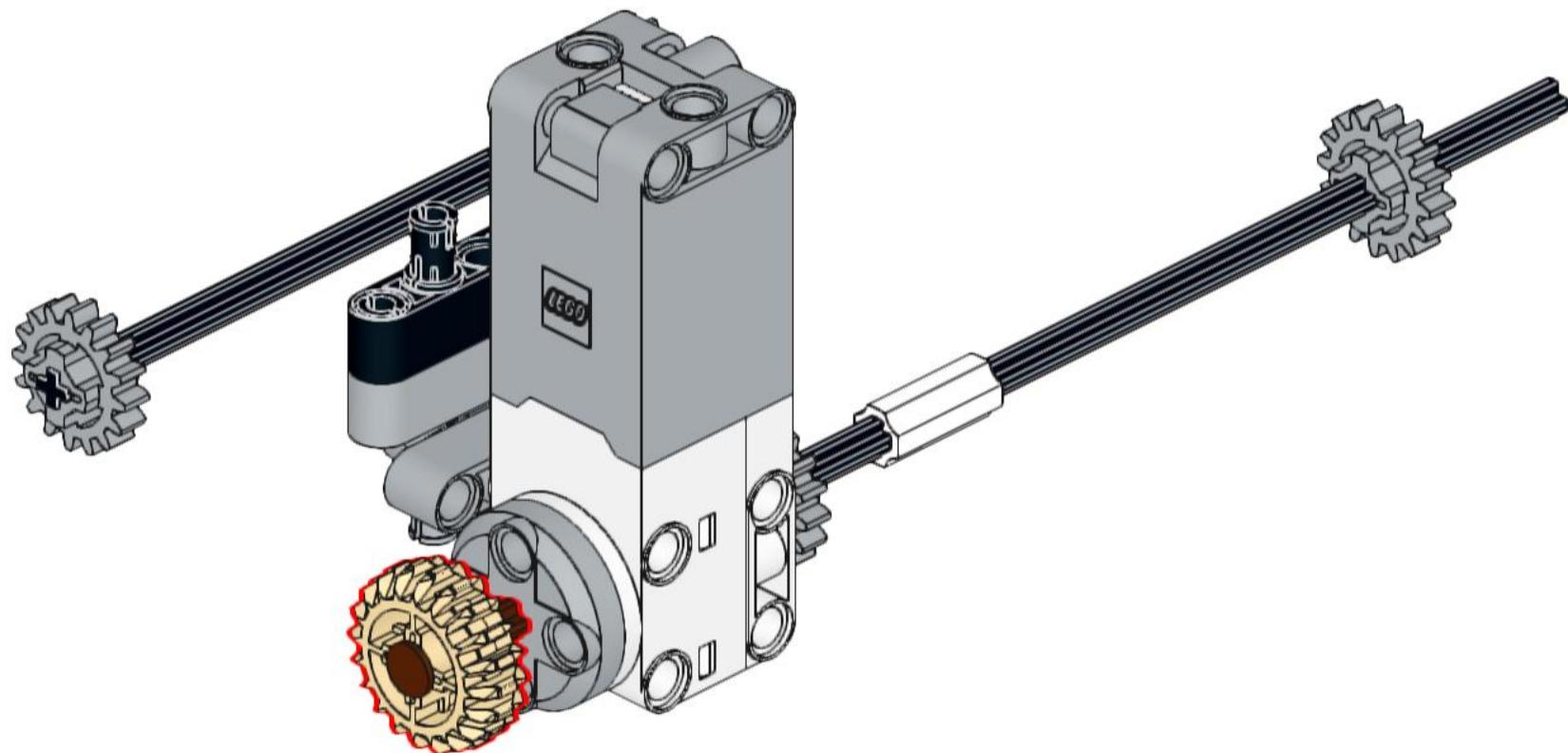
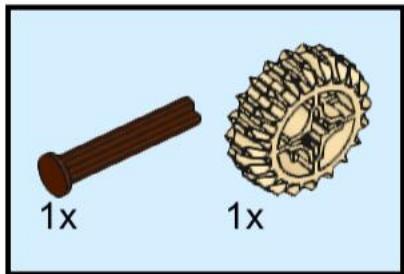


Then Rotate it so it clicks  
into the pins

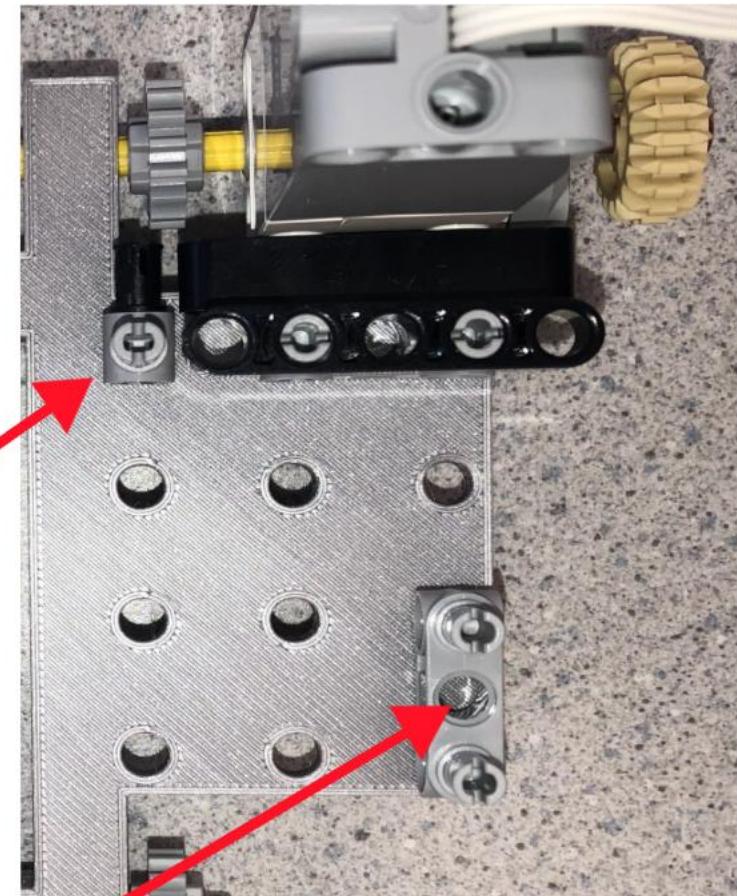
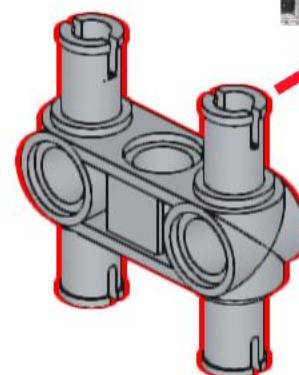
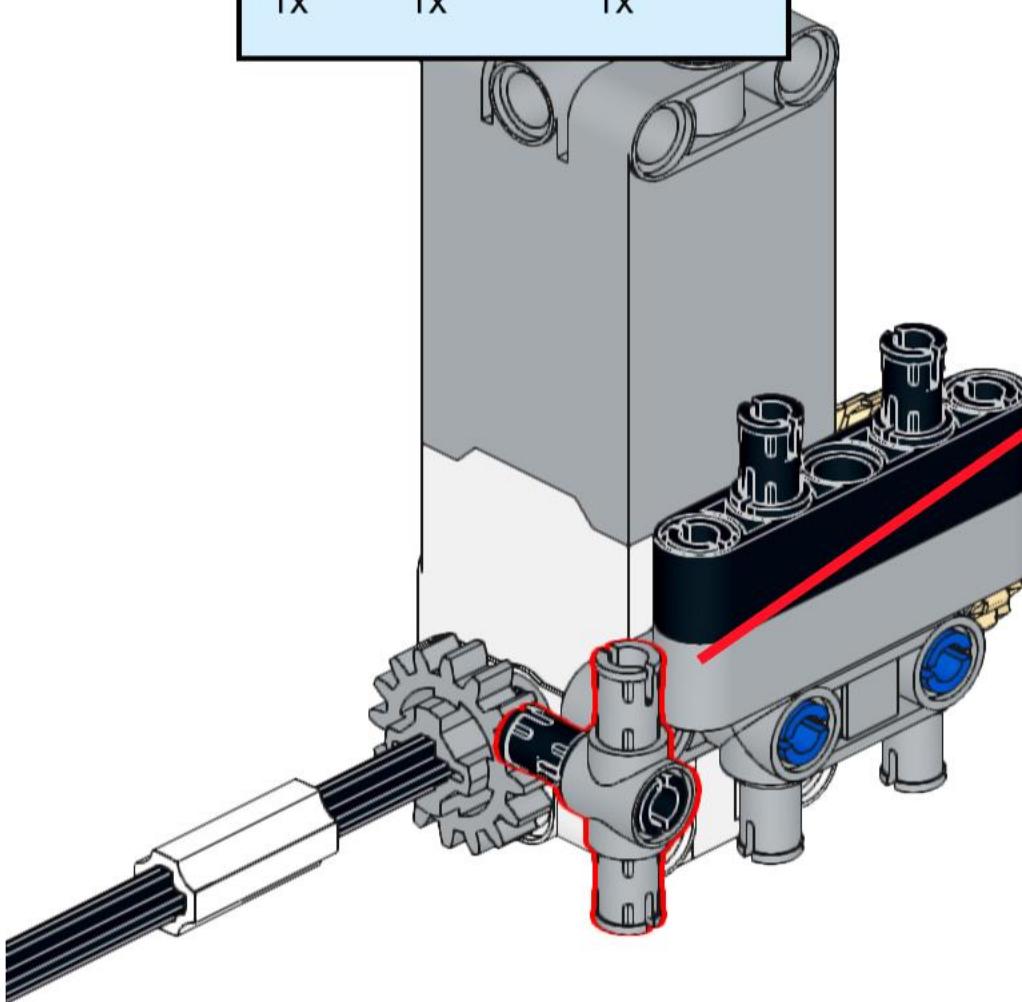
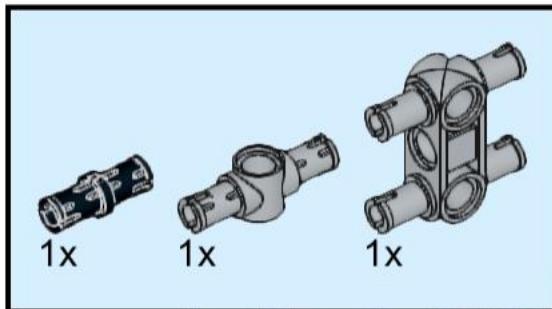
**11**



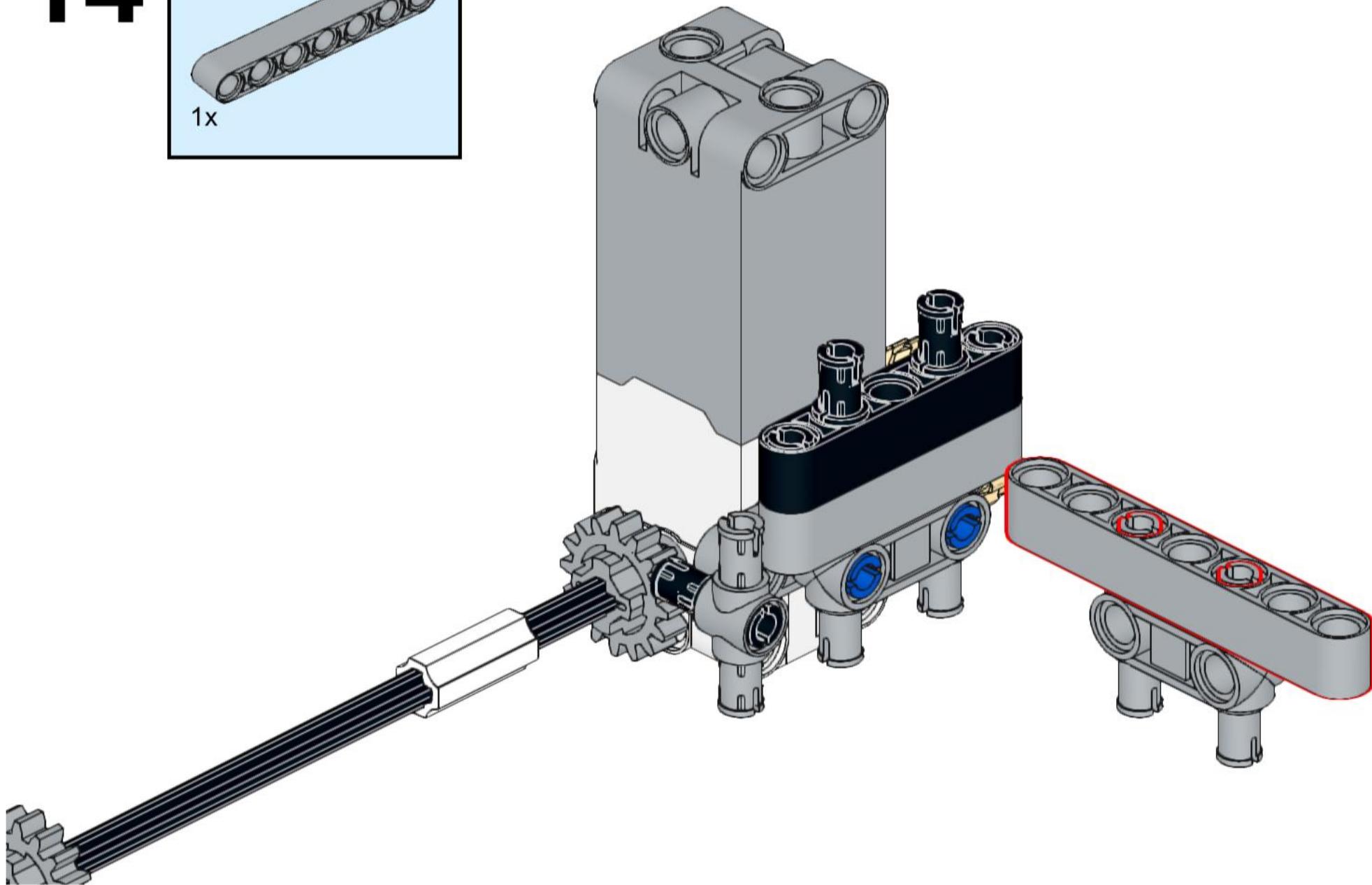
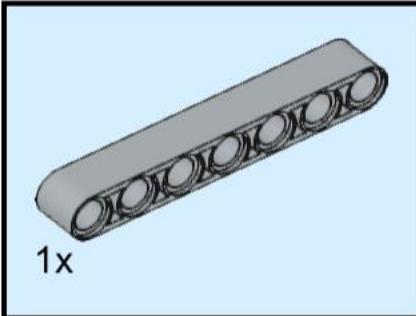
**12**



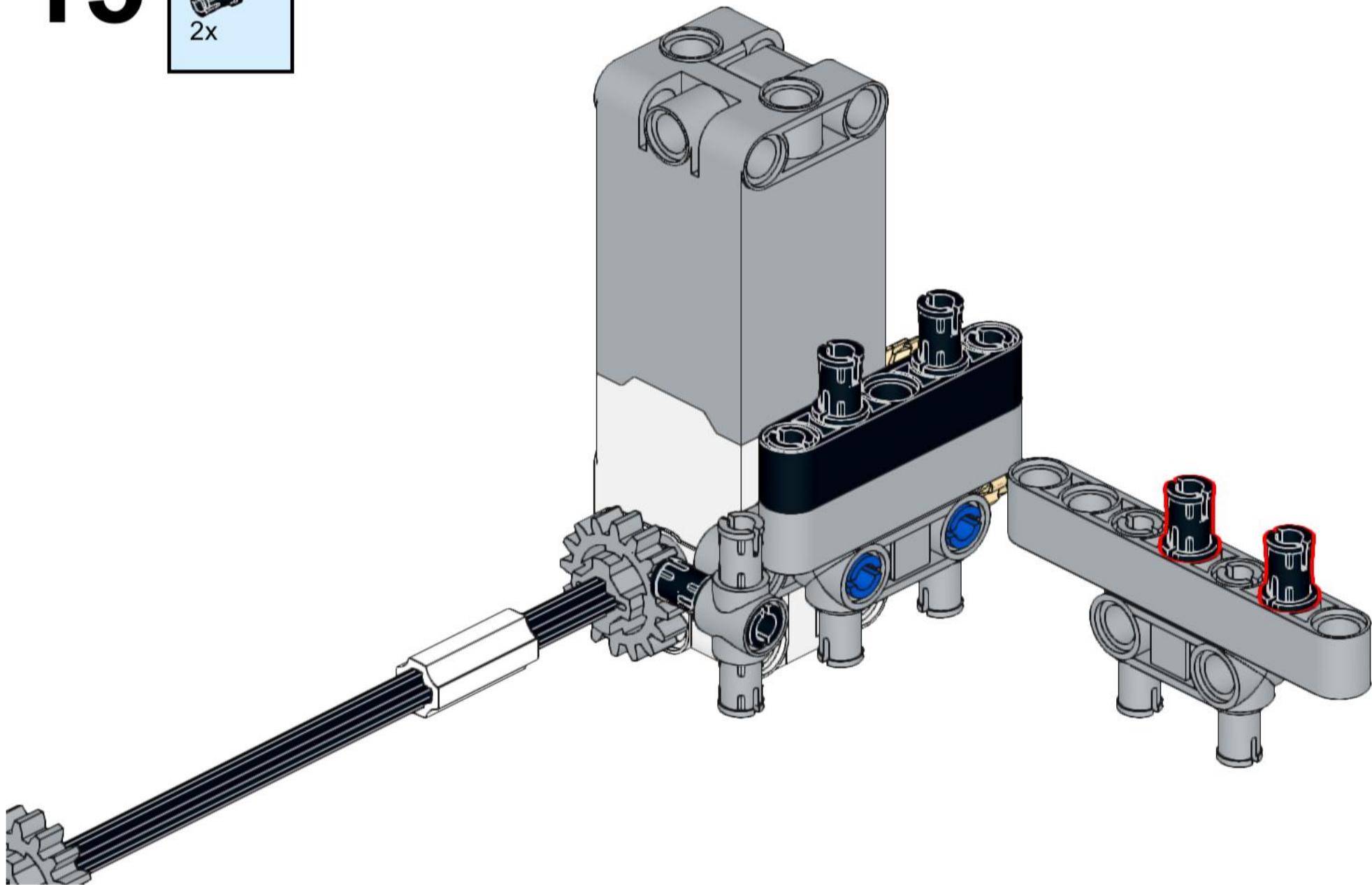
**13**



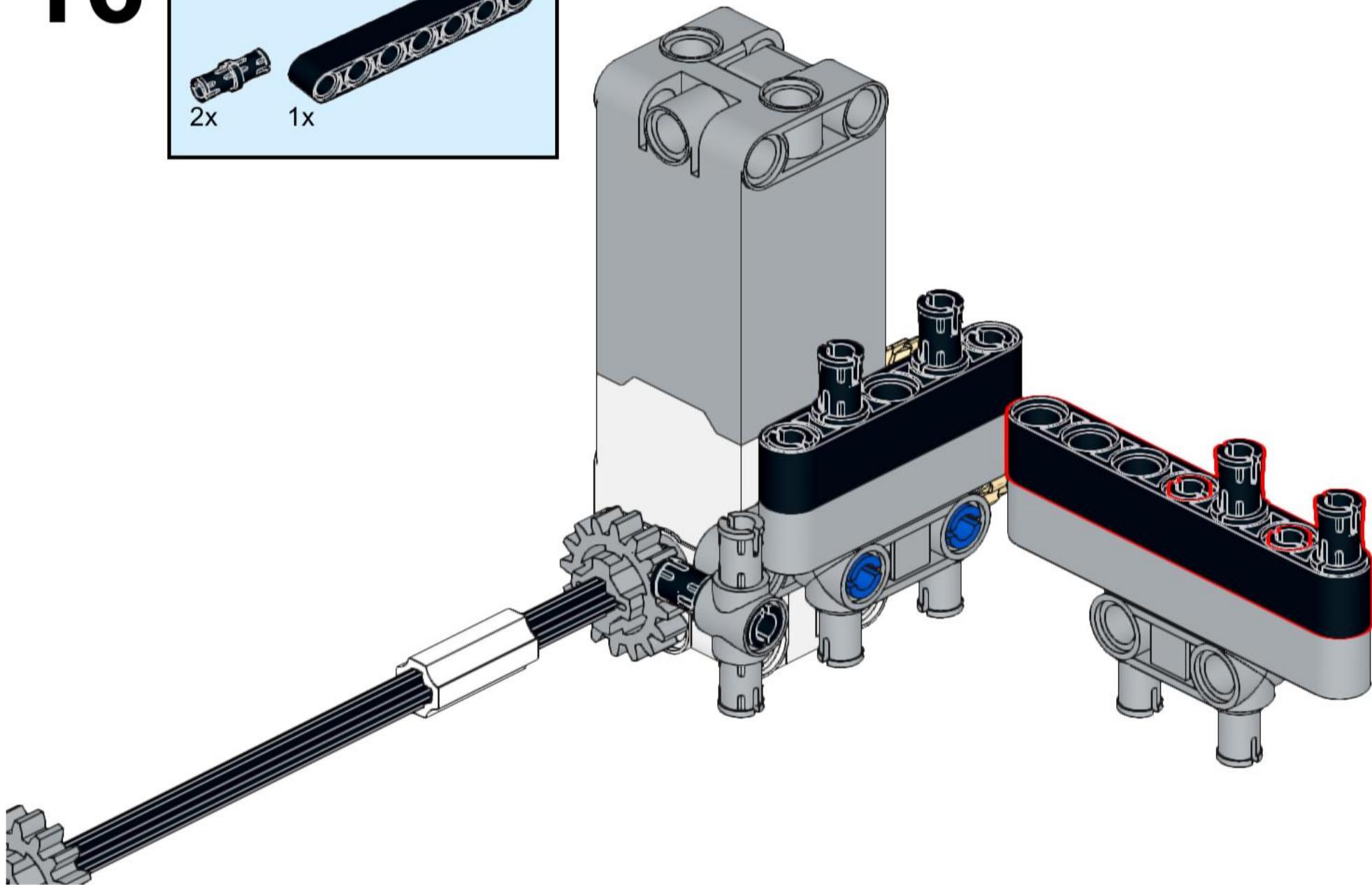
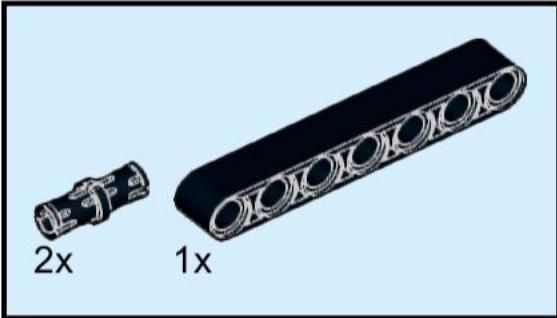
**14**



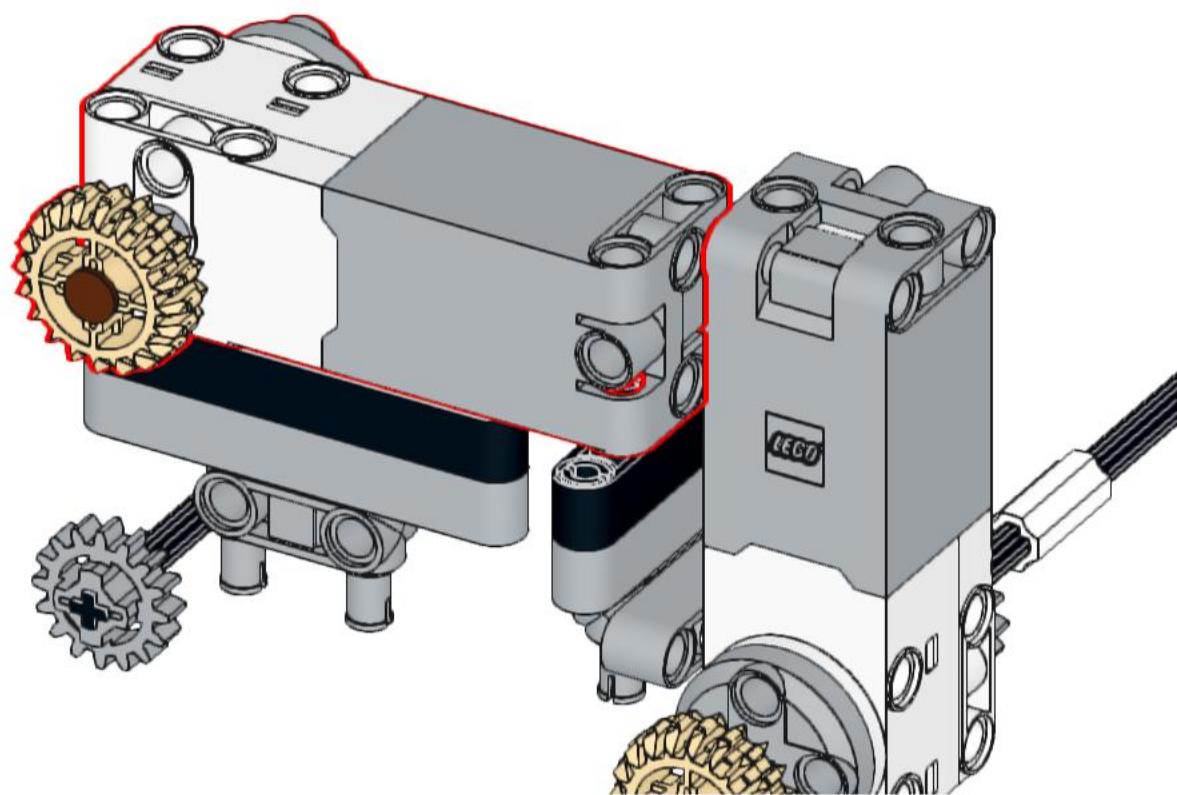
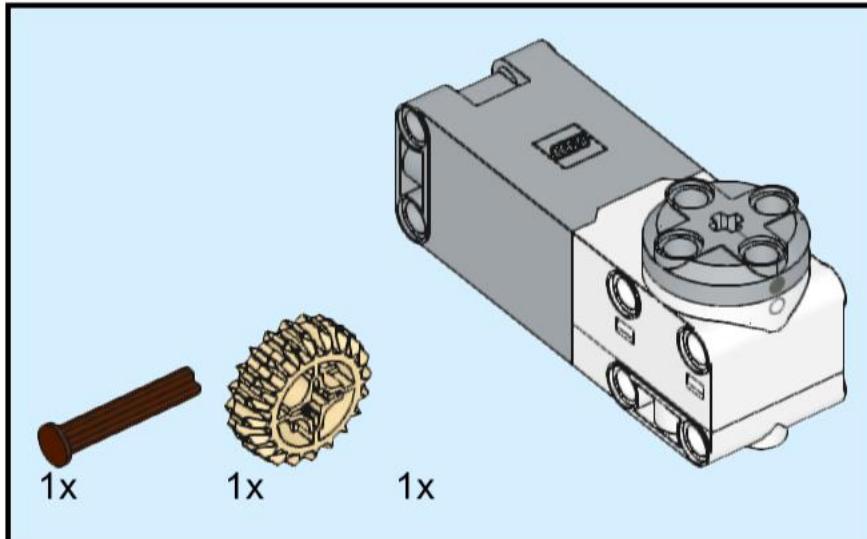
**15**



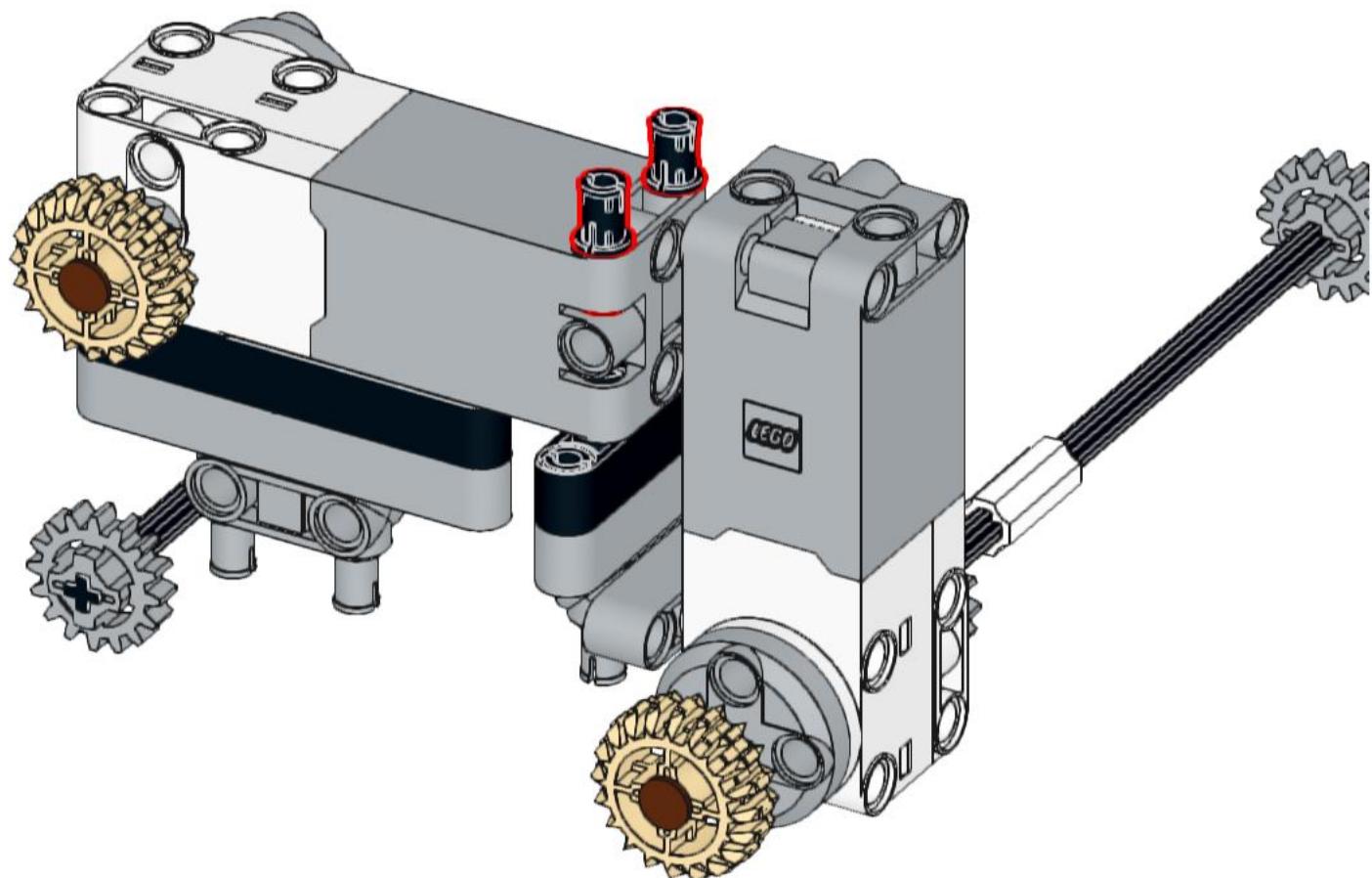
**16**



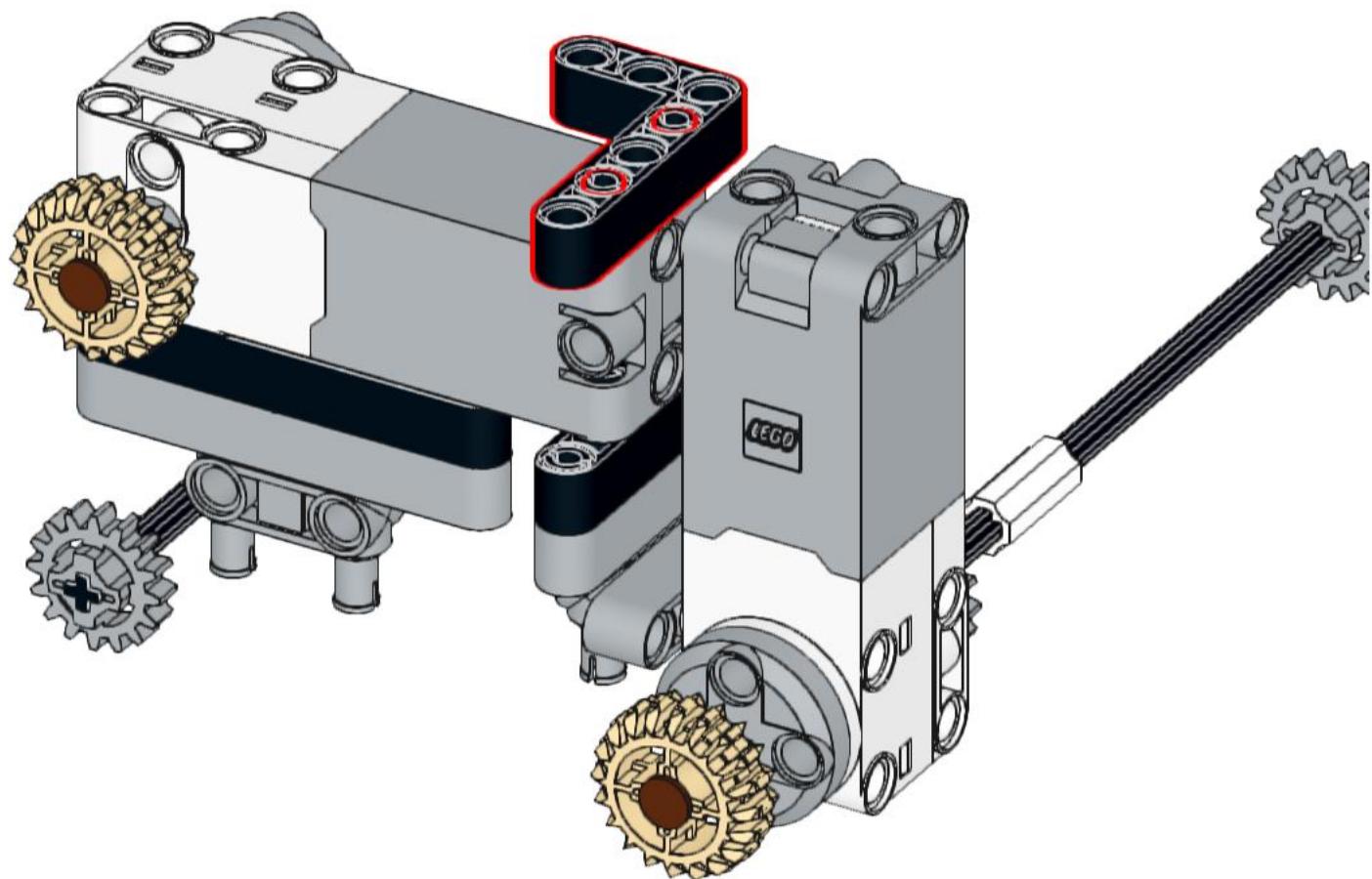
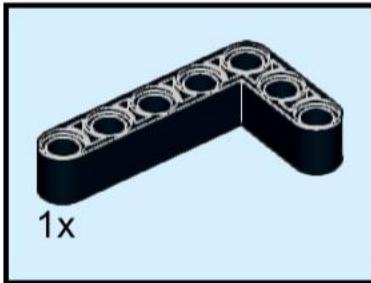
**17**



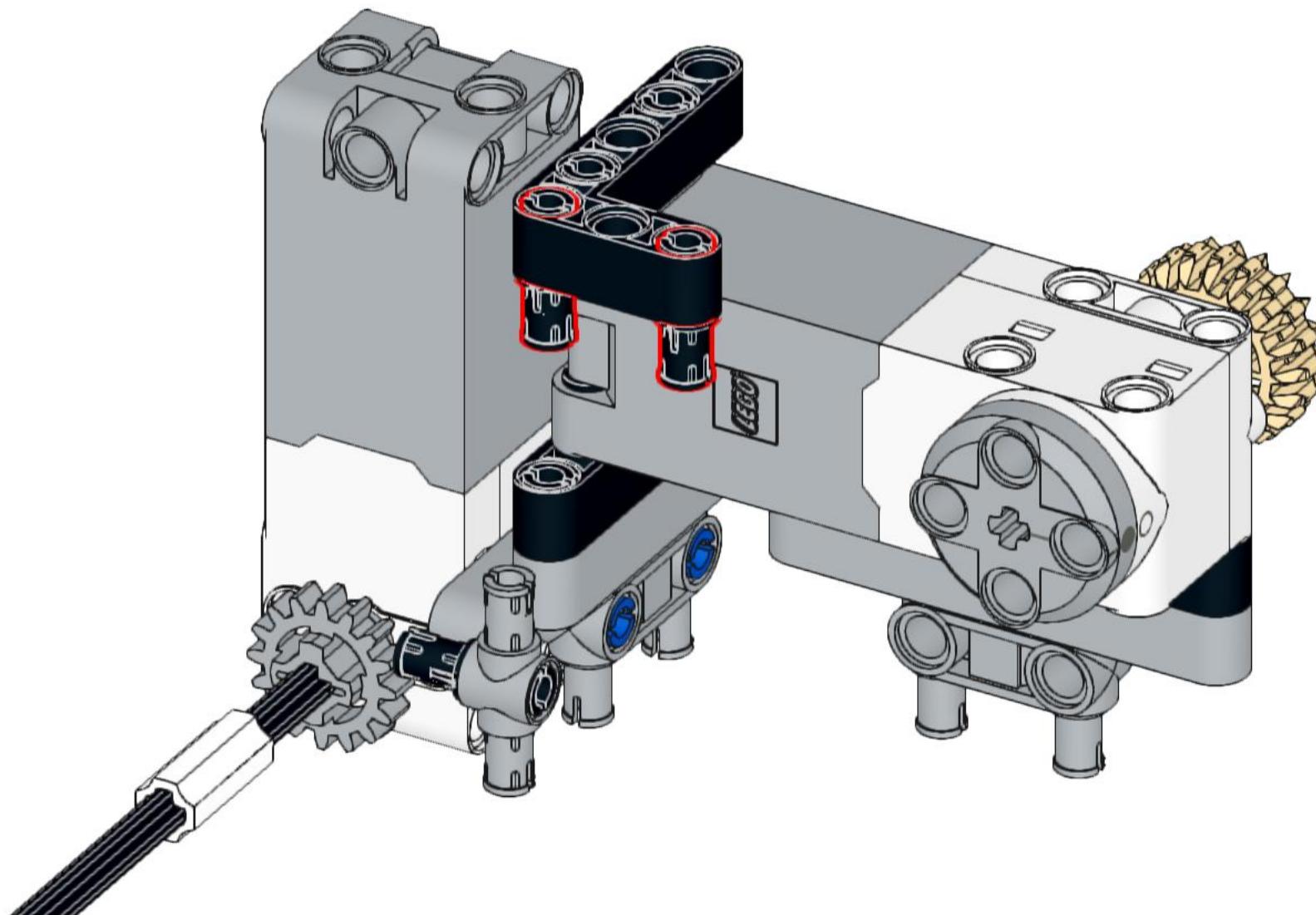
**18**



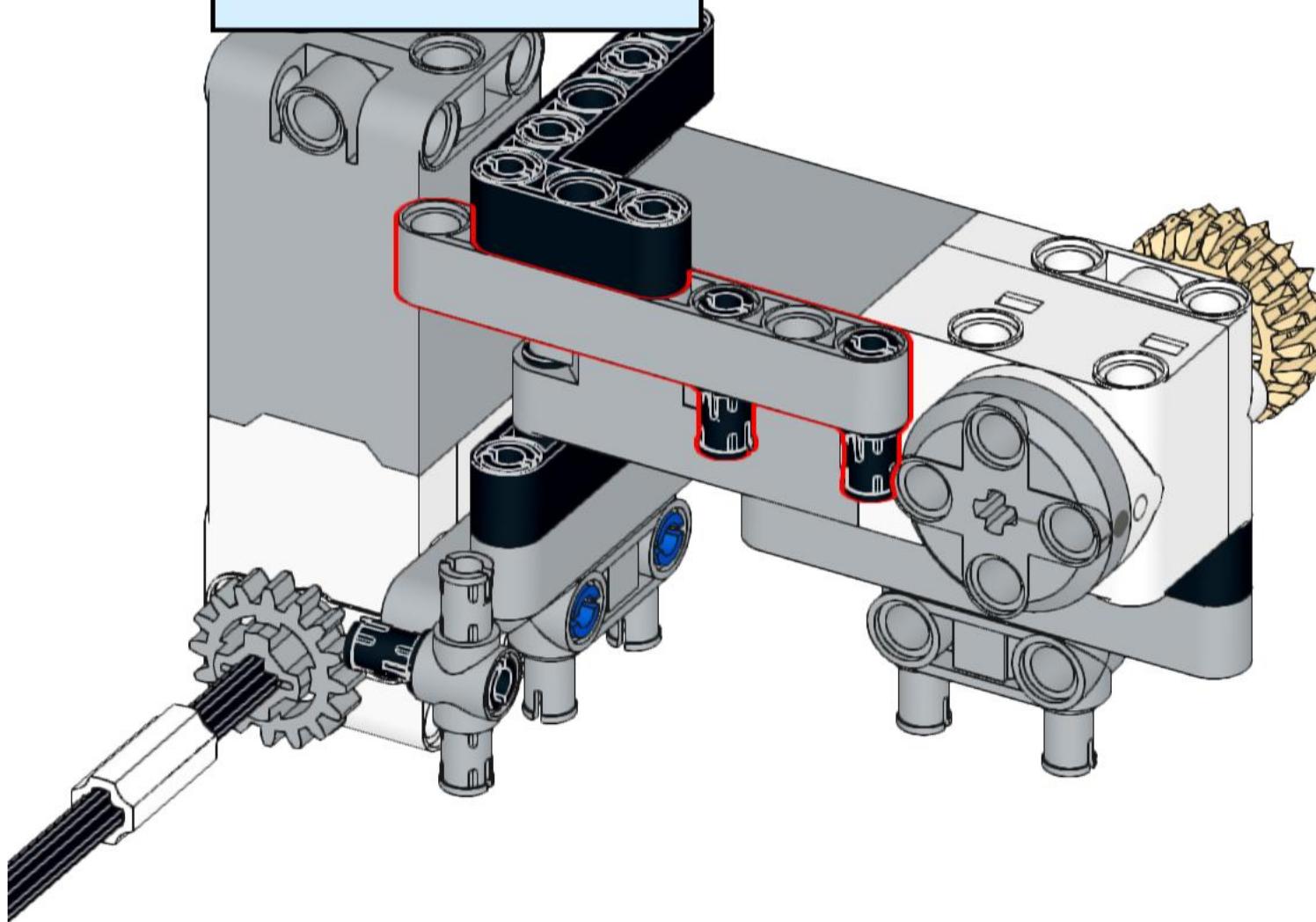
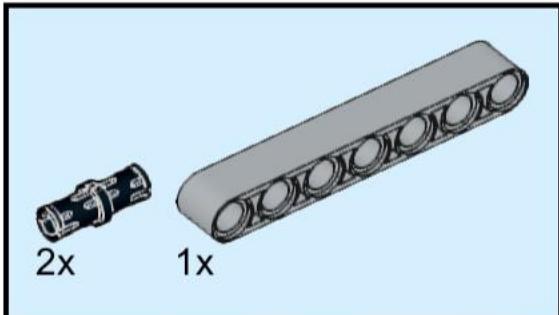
**19**



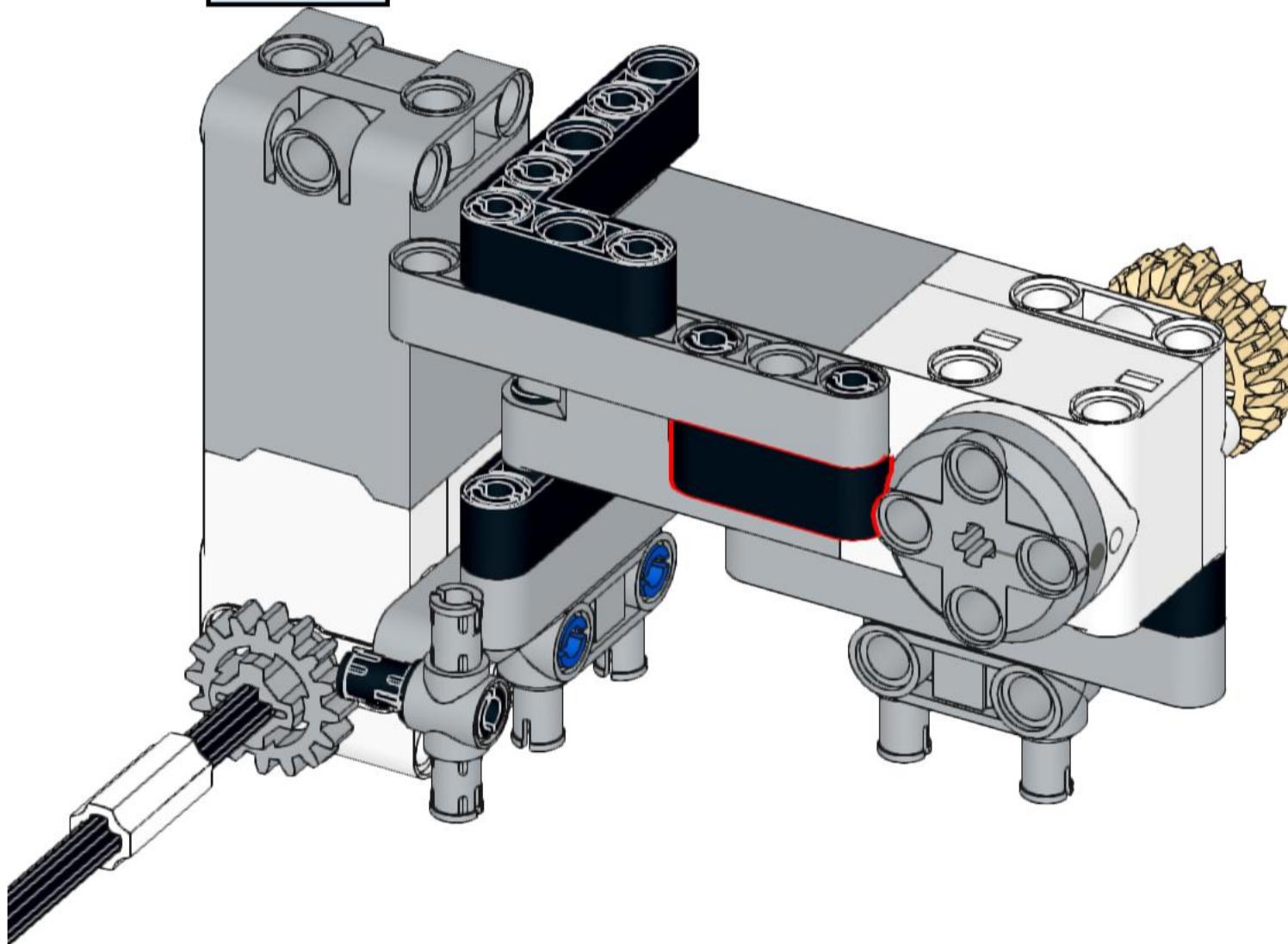
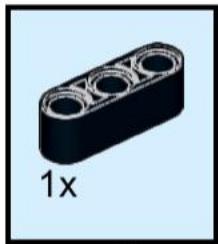
**20**



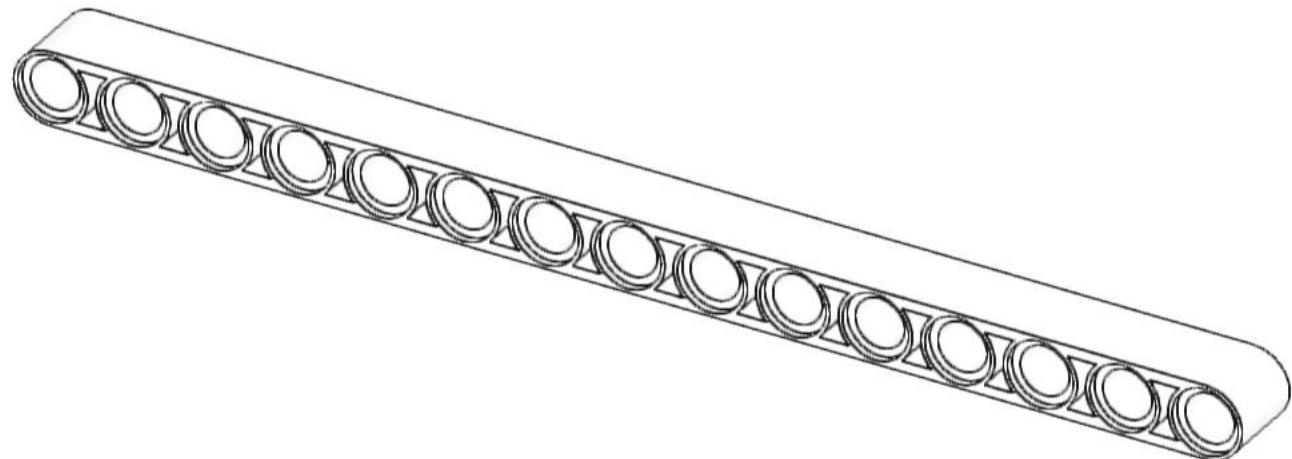
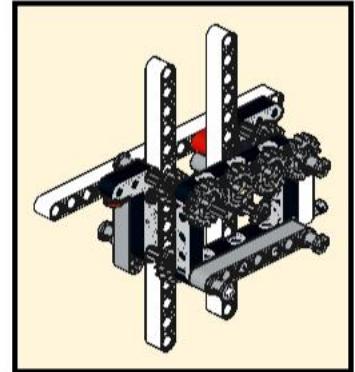
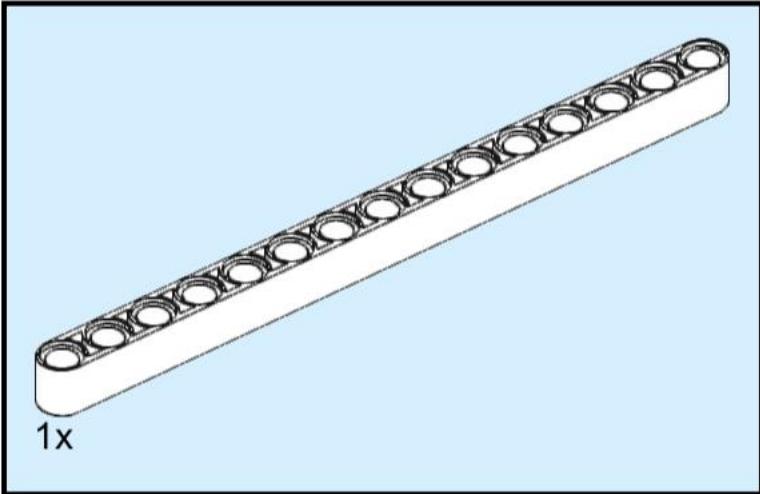
**21**



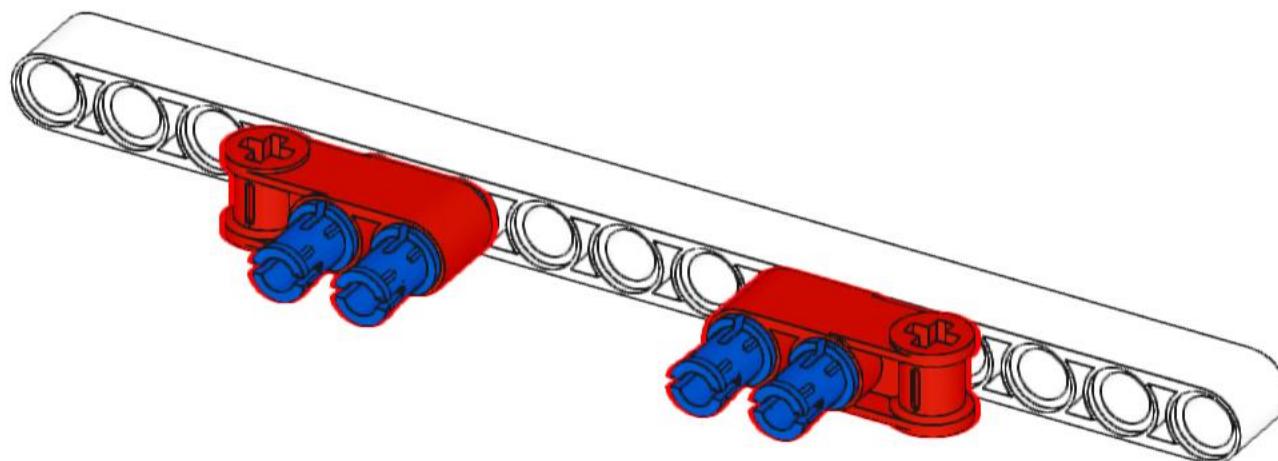
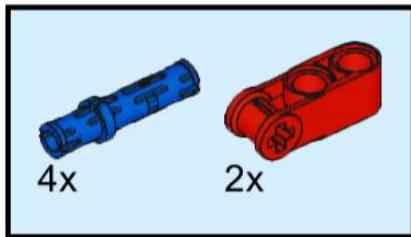
**22**



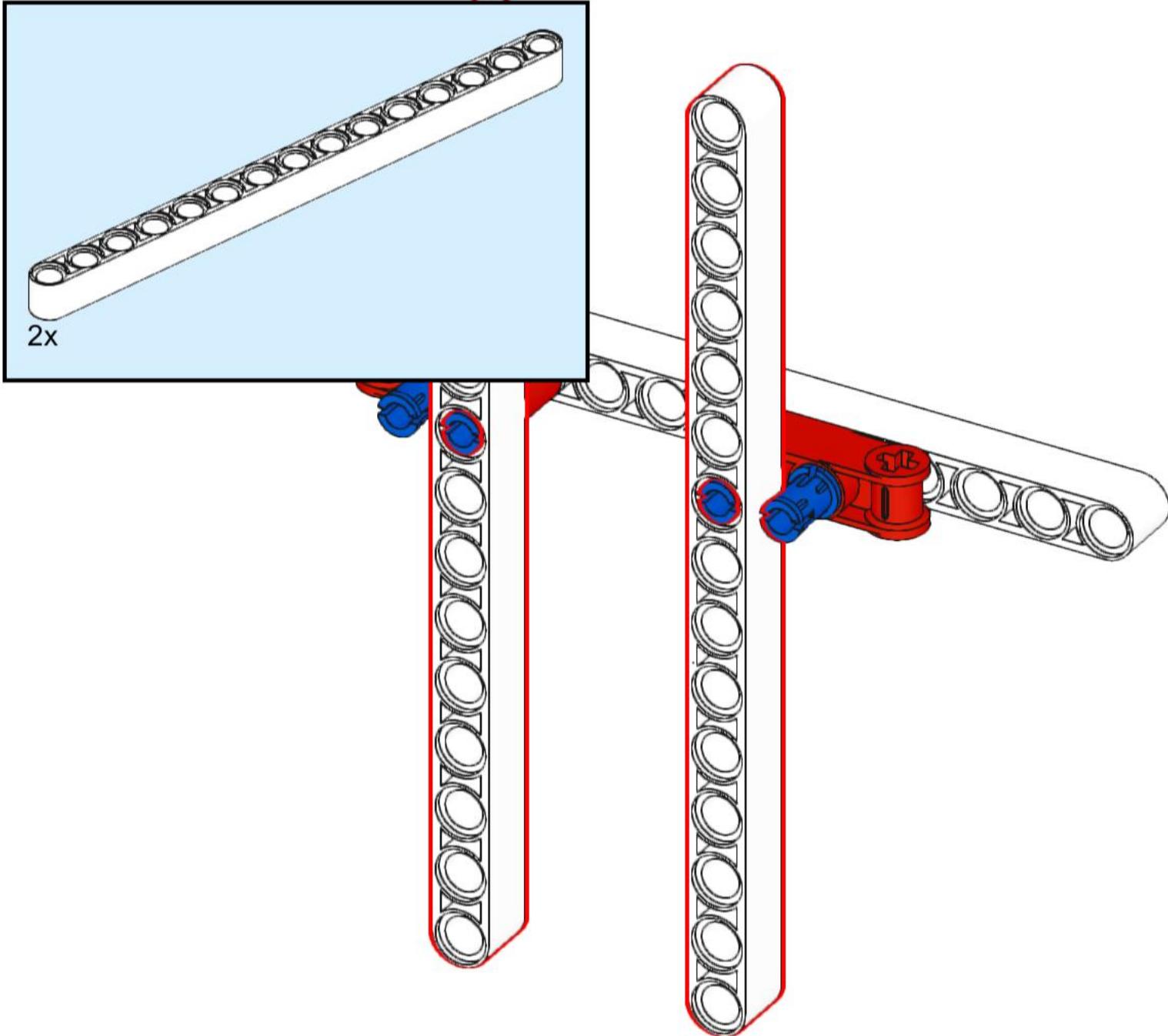
**23**



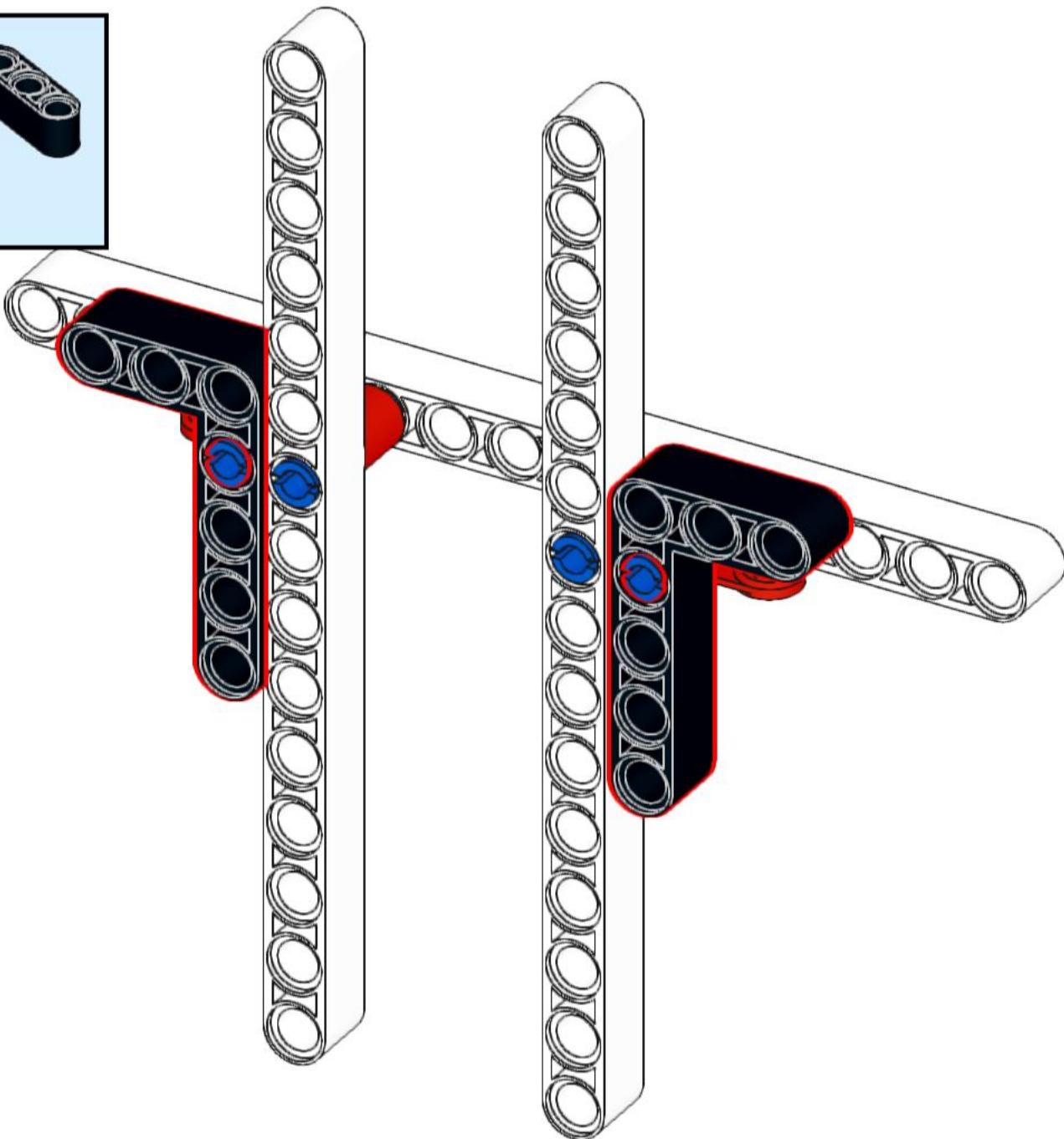
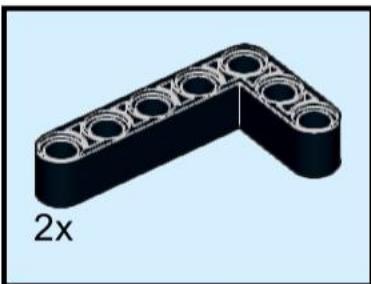
**24**



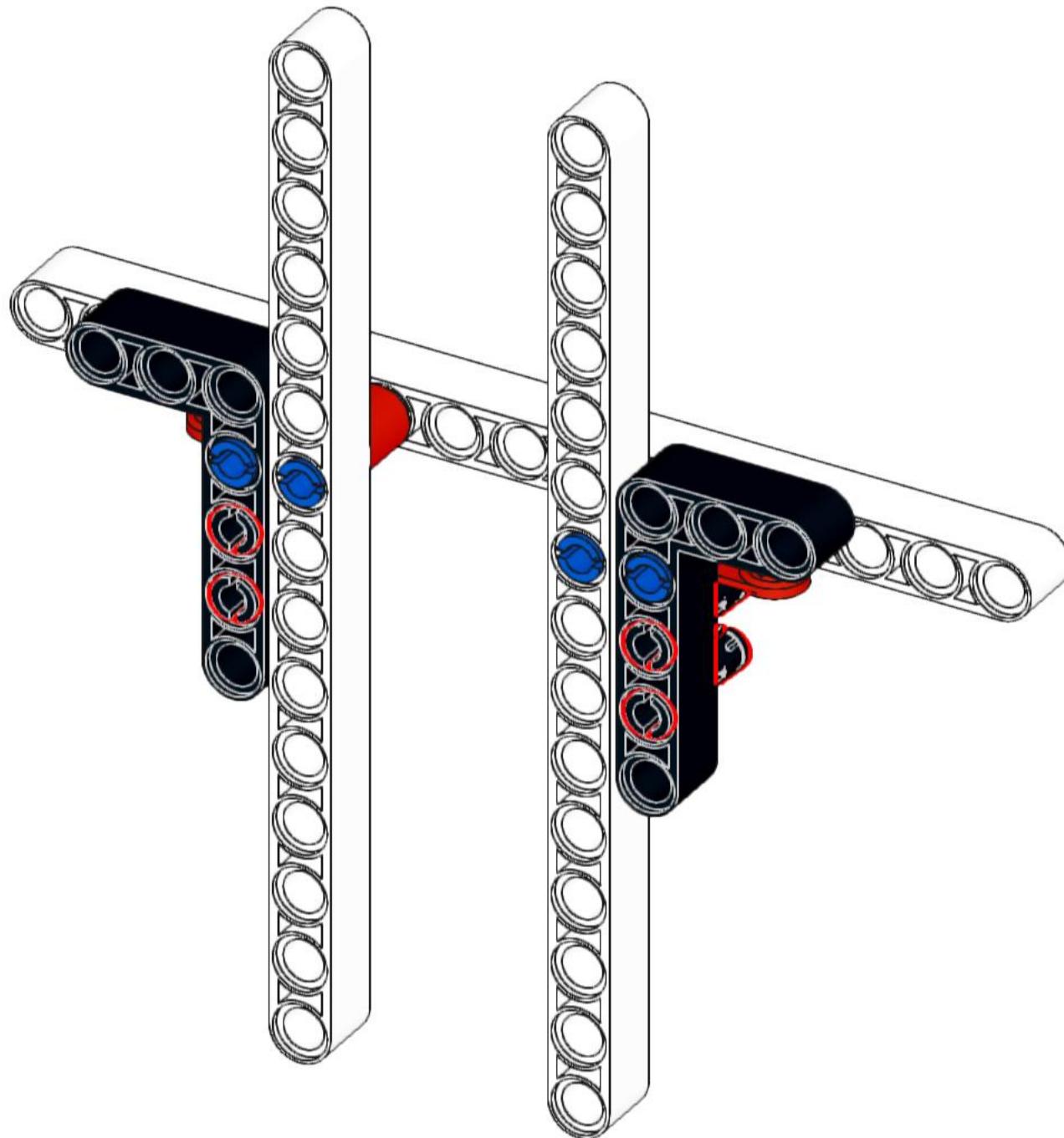
**25**



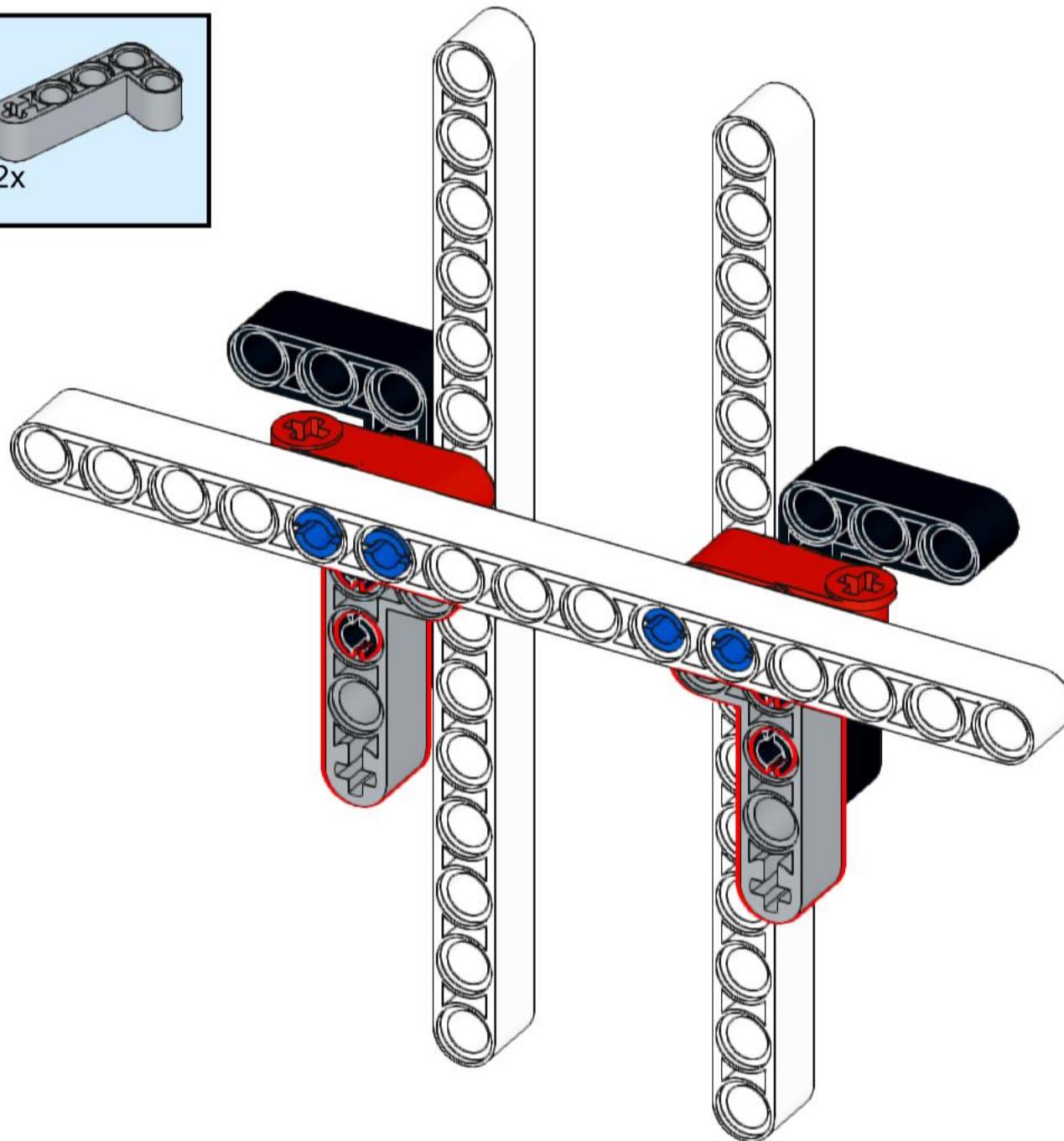
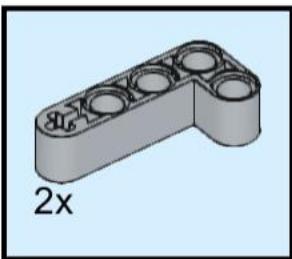
**26**



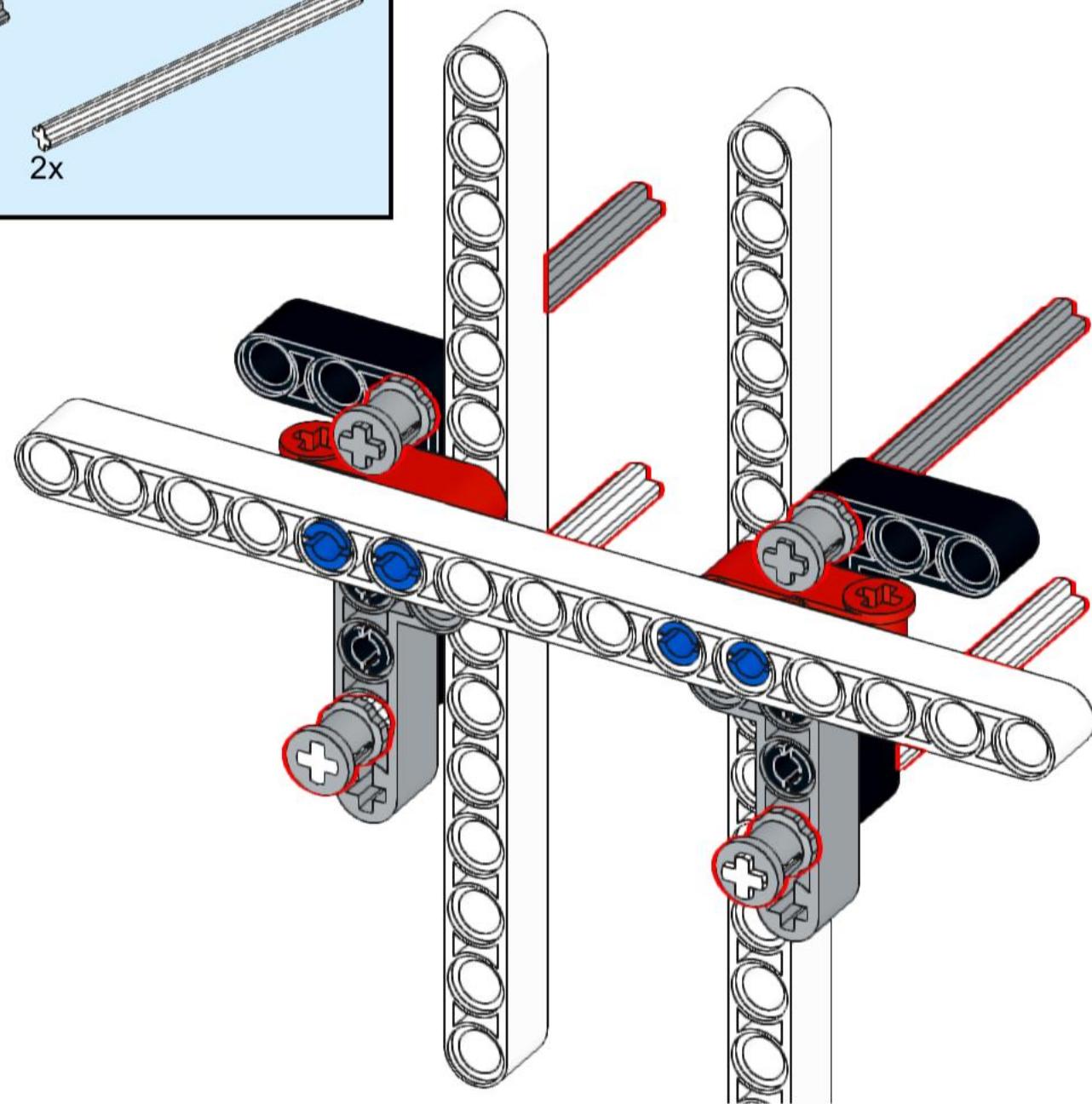
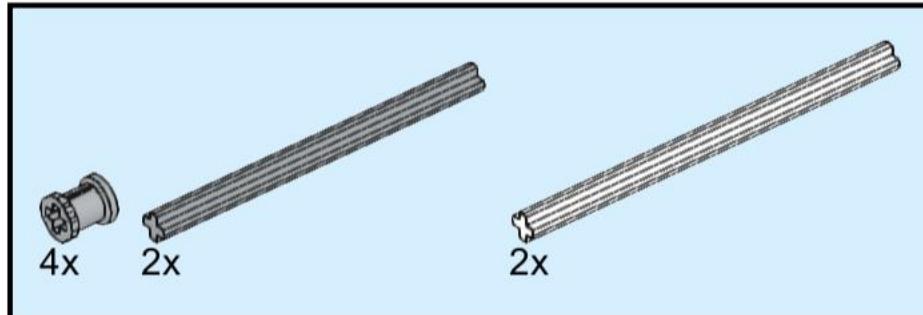
**27**



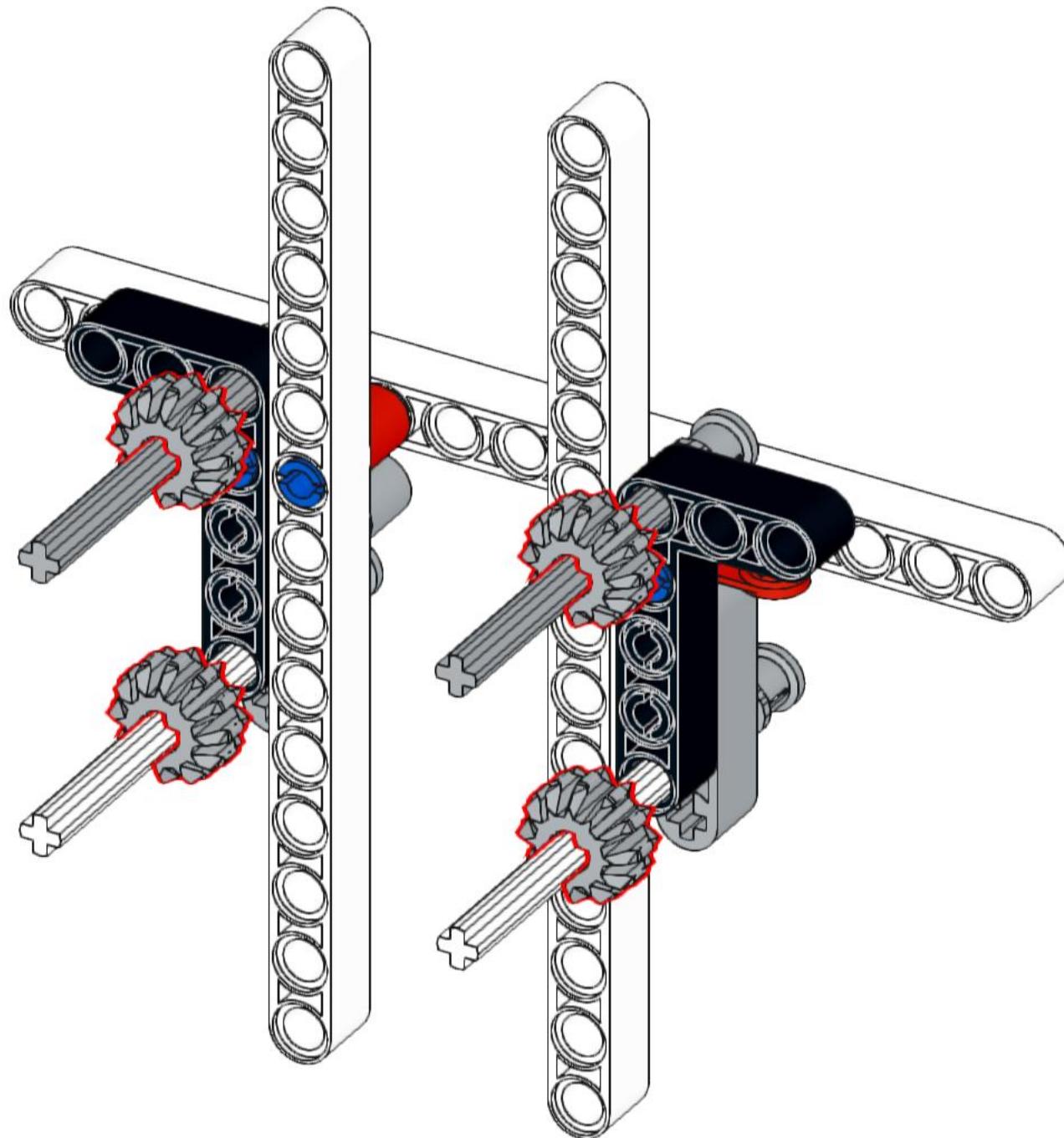
**28**

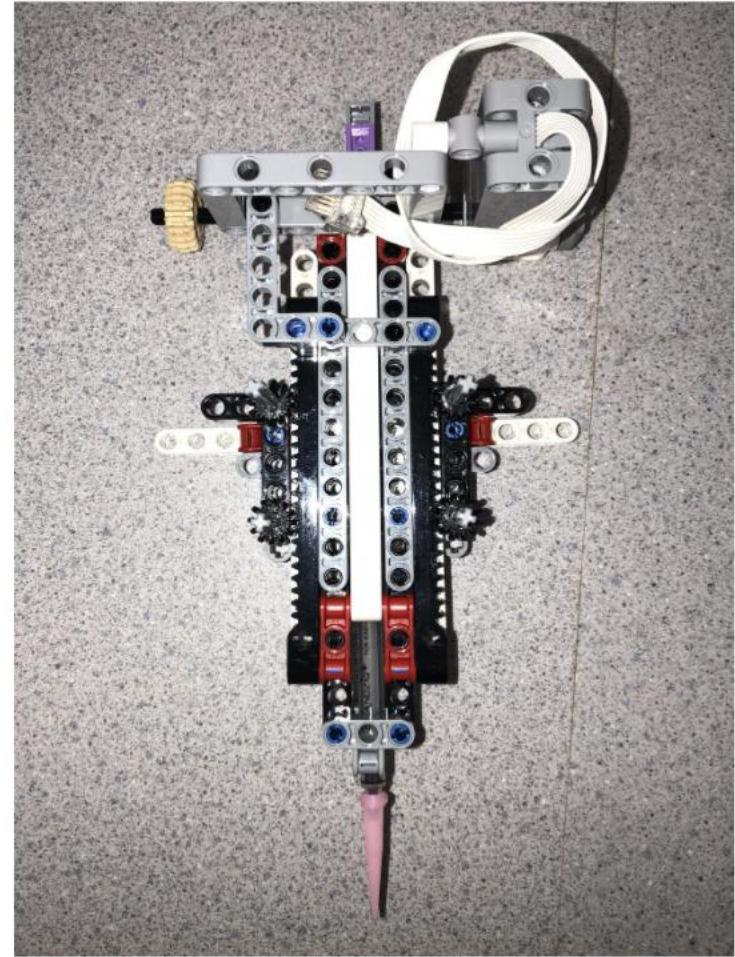
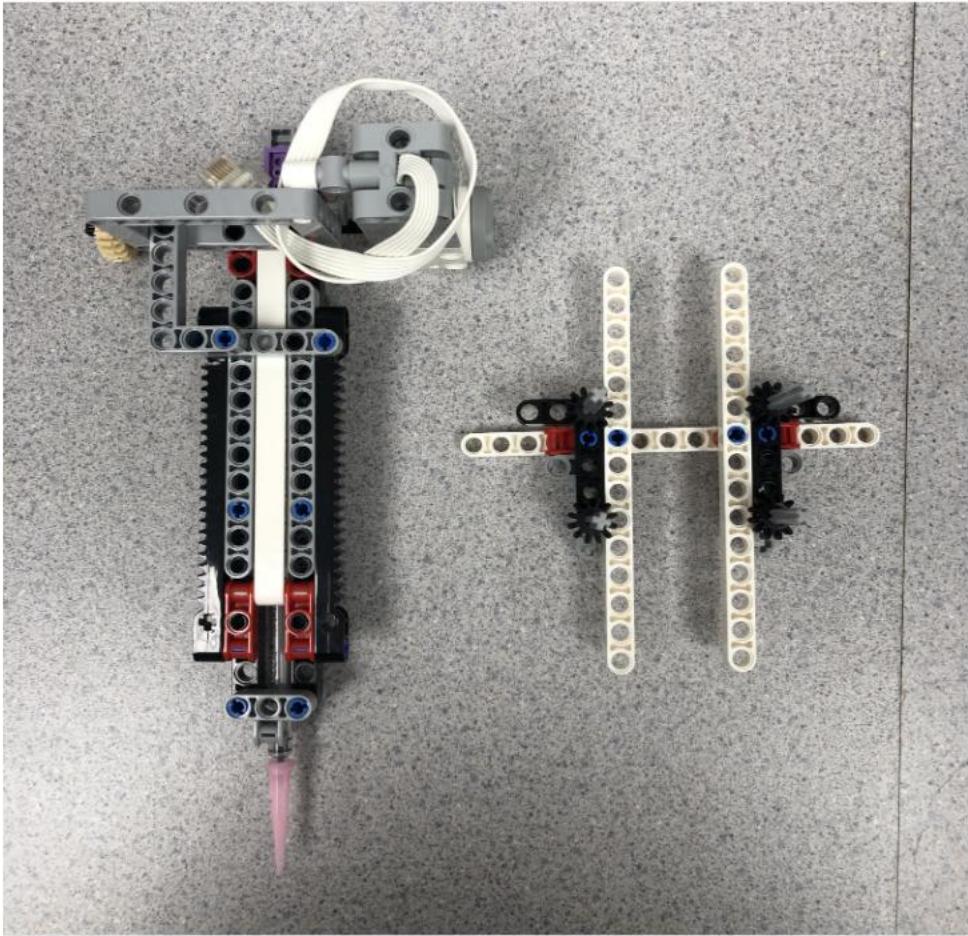


**29**



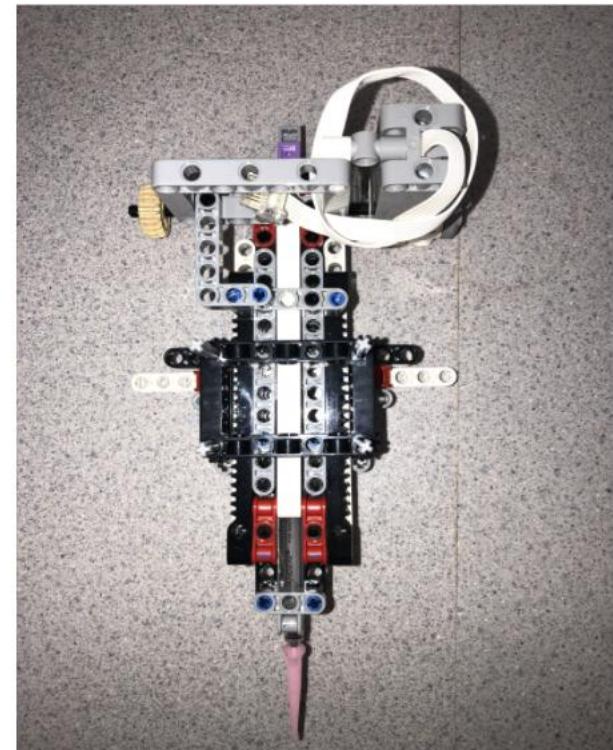
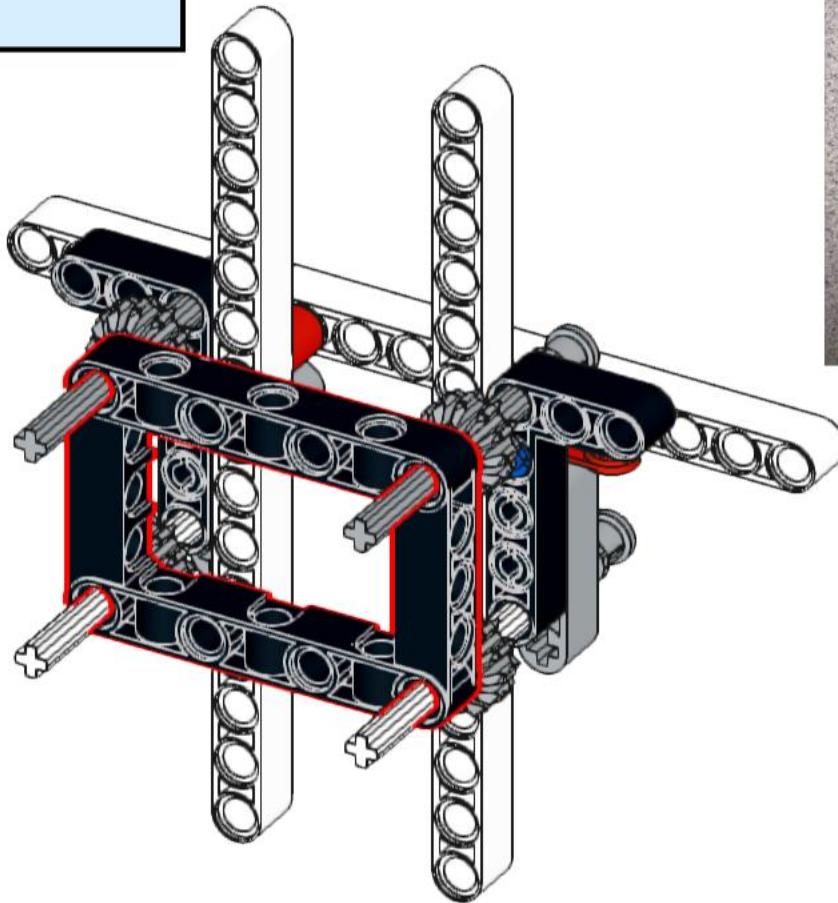
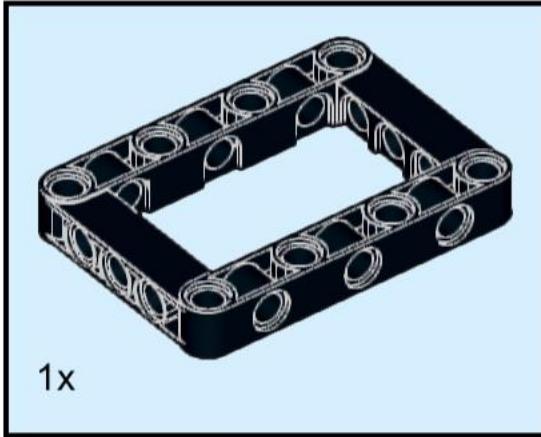
**30**



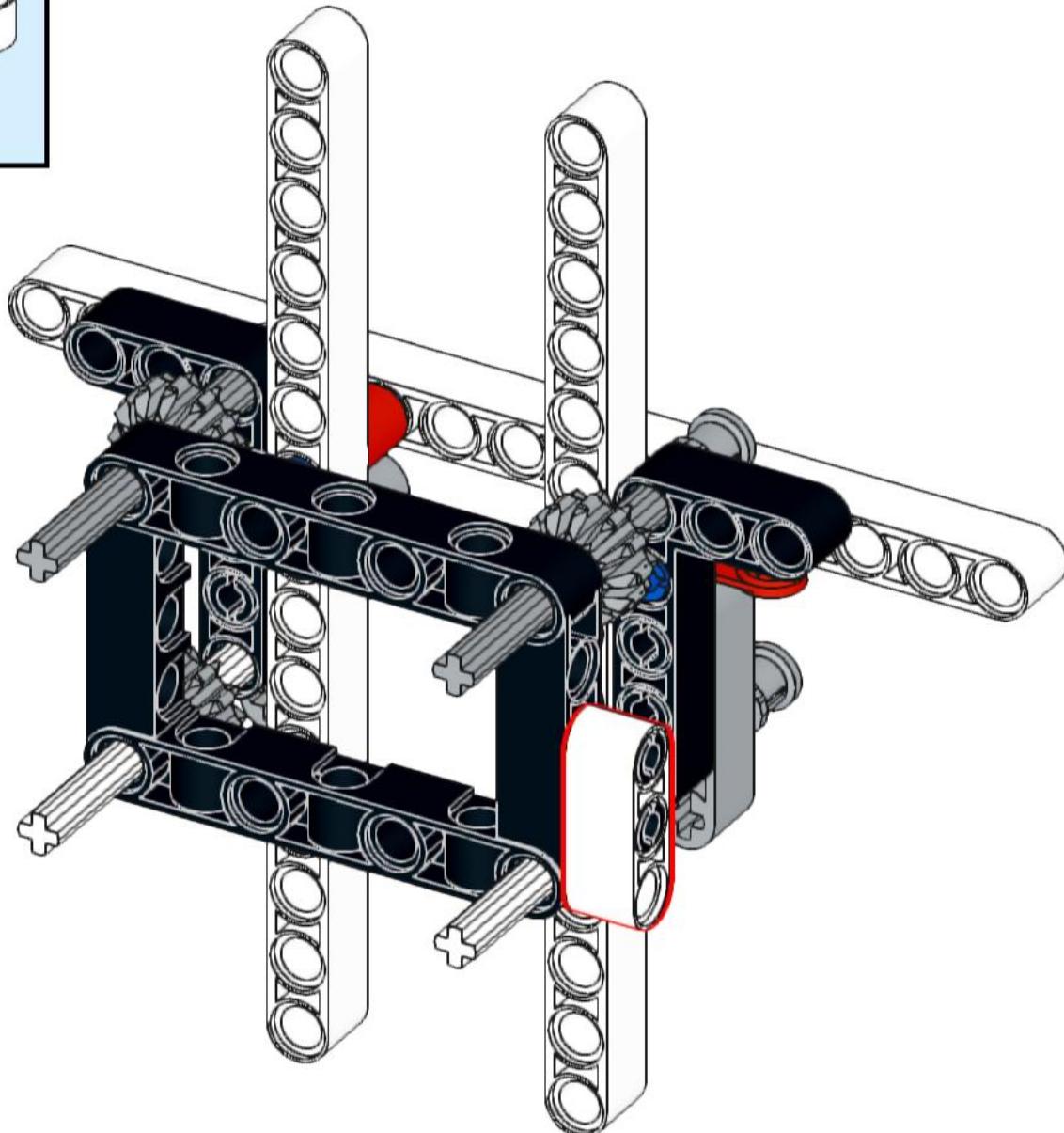
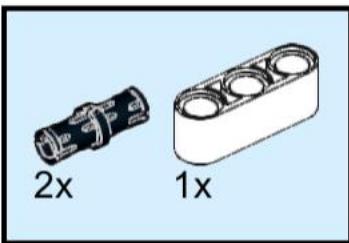


This is the easiest time to insert the syringe holder + plunger assembly within the lift mechanism. Place the assembly so that the gear racks fit into the teeth of the 4 small gears (right), then continue building on top of this

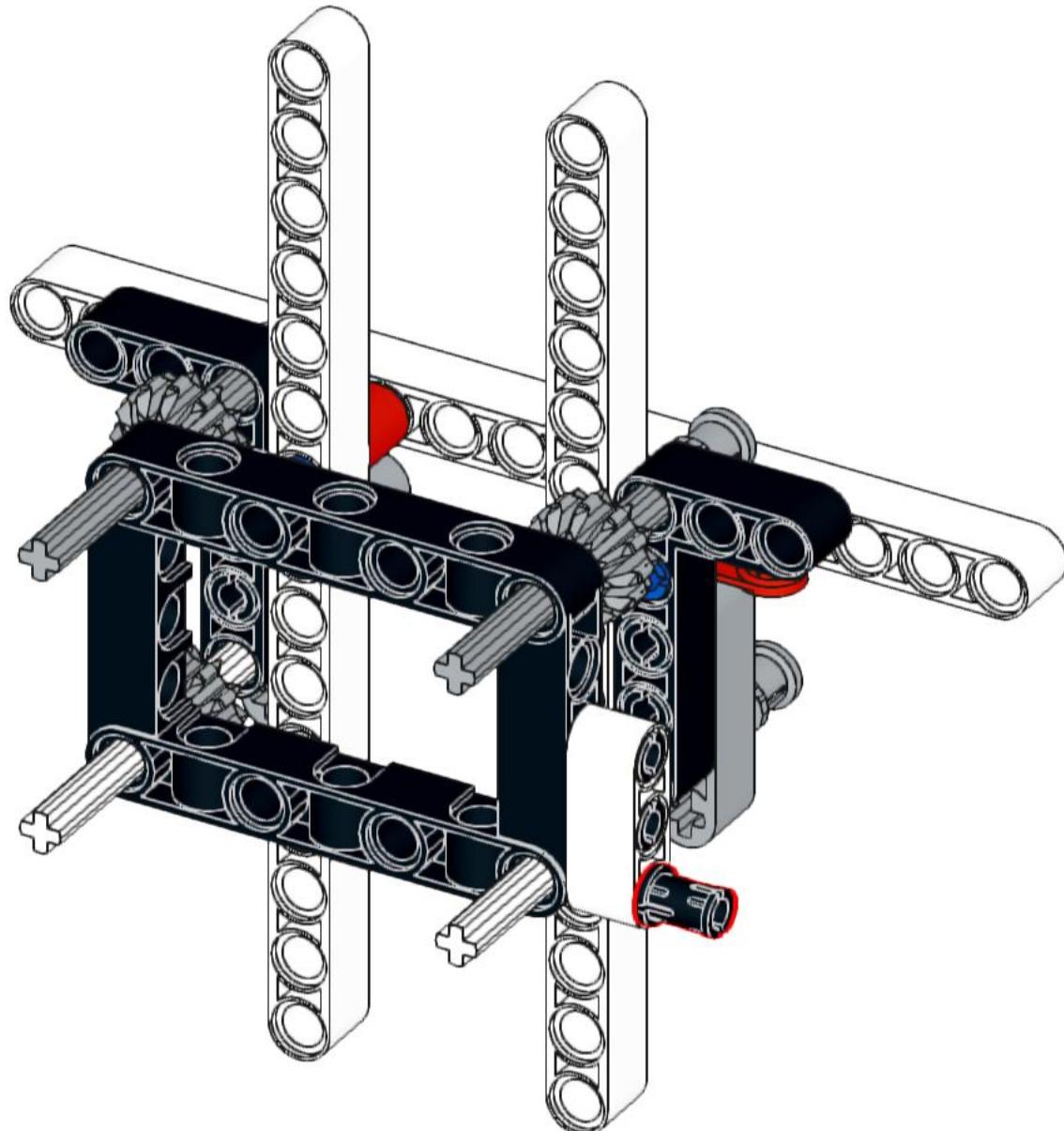
**31**



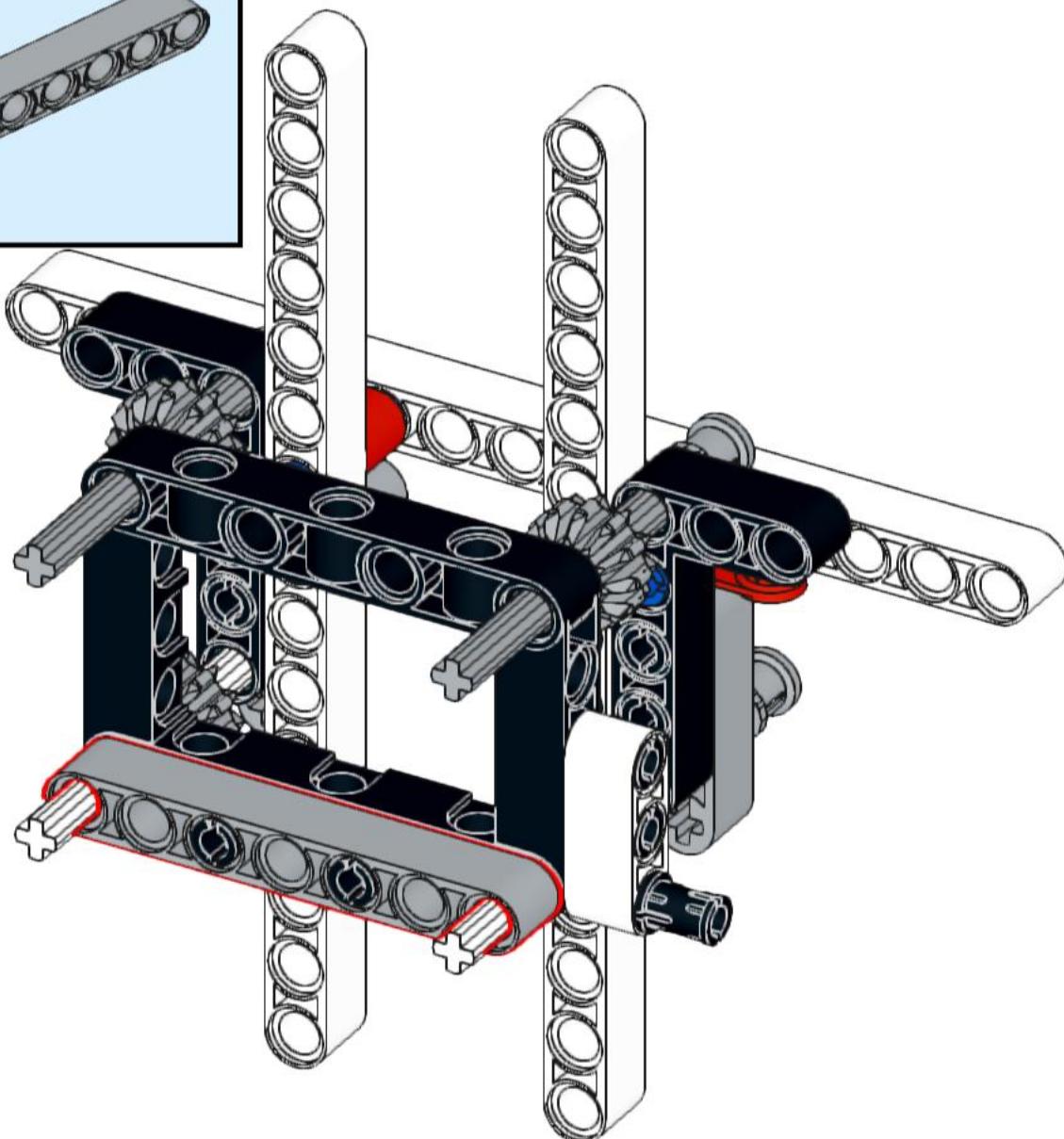
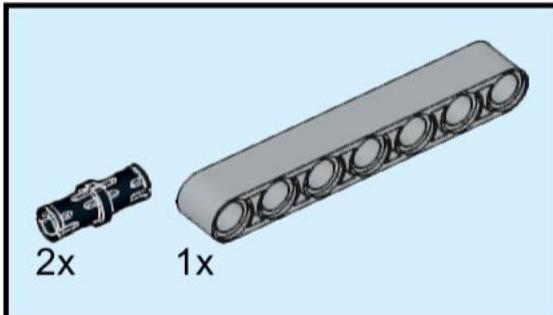
**32**



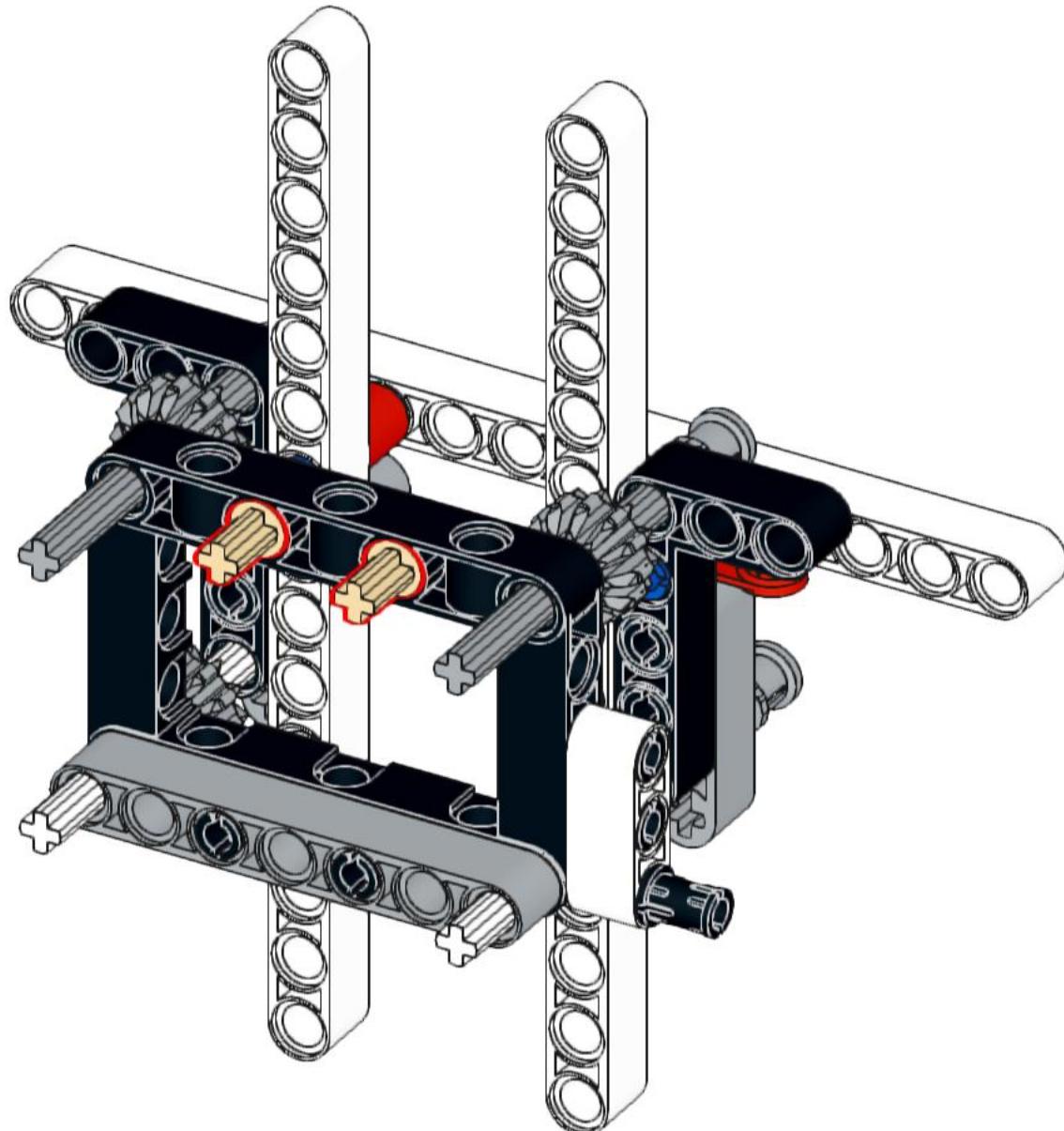
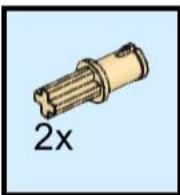
**33**



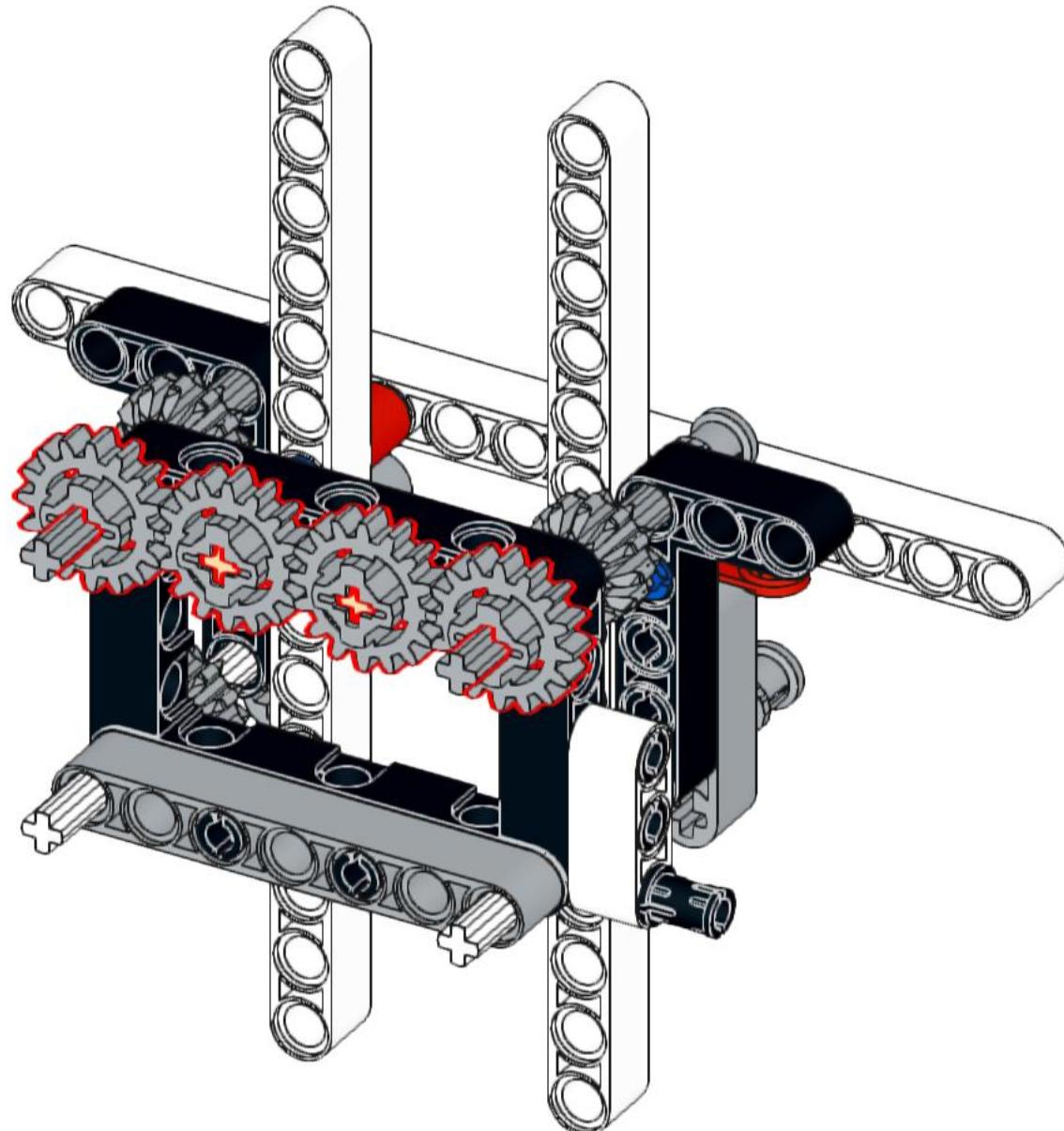
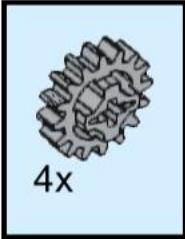
**34**



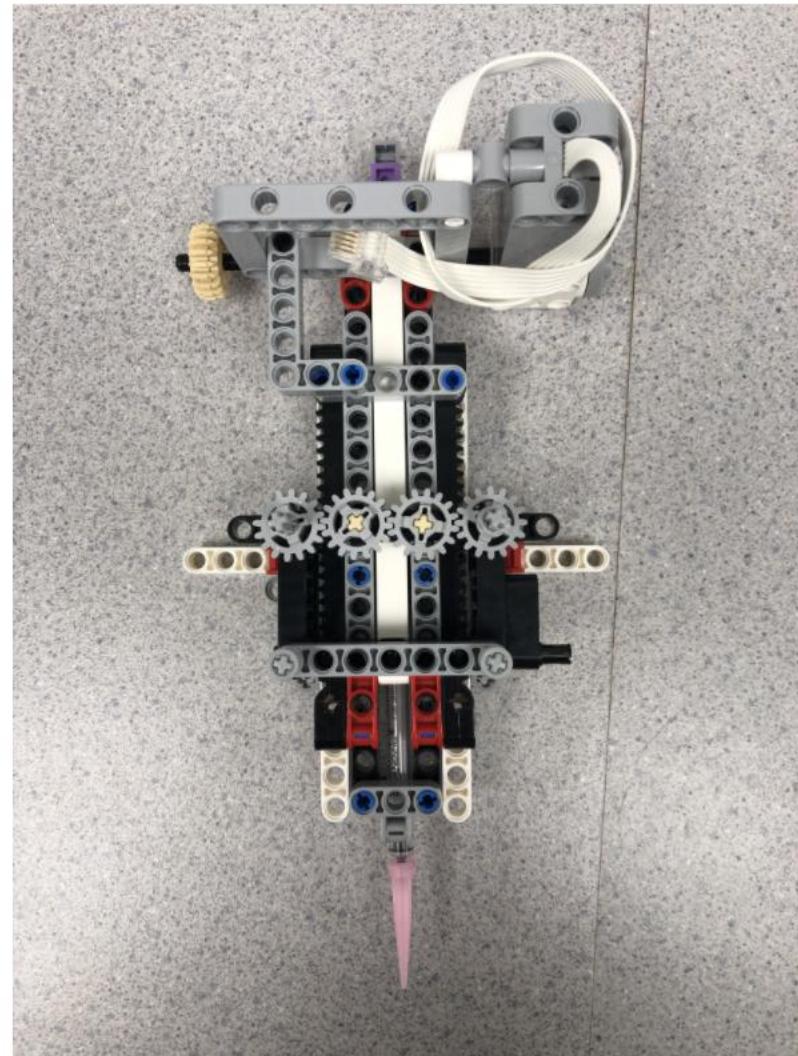
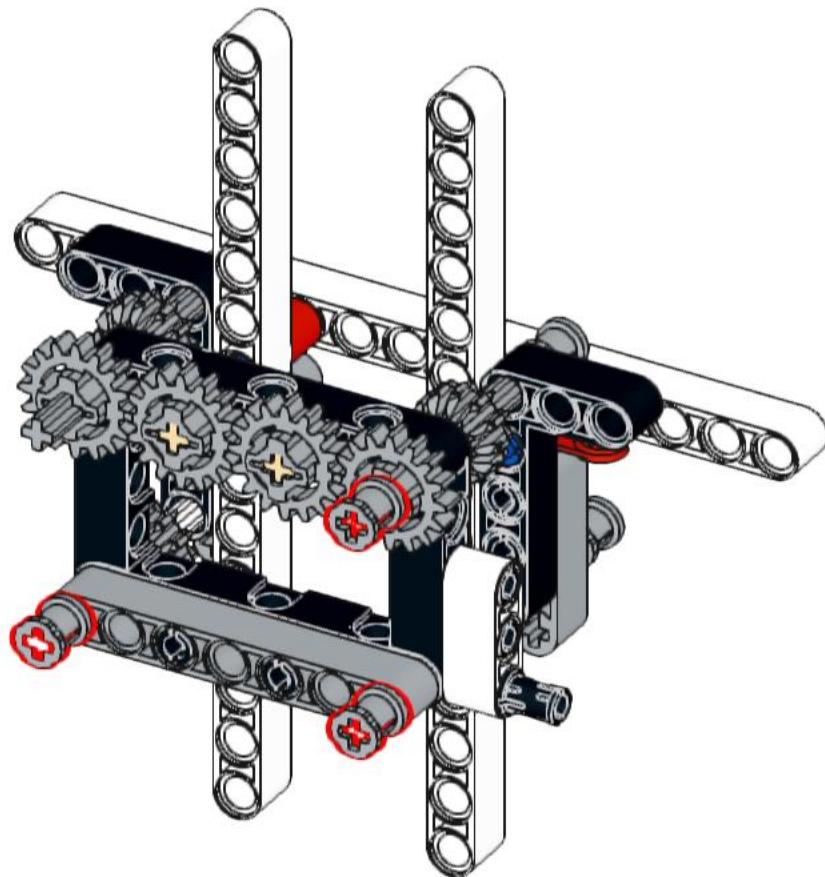
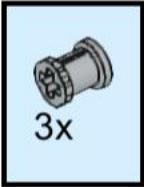
**35**



**36**

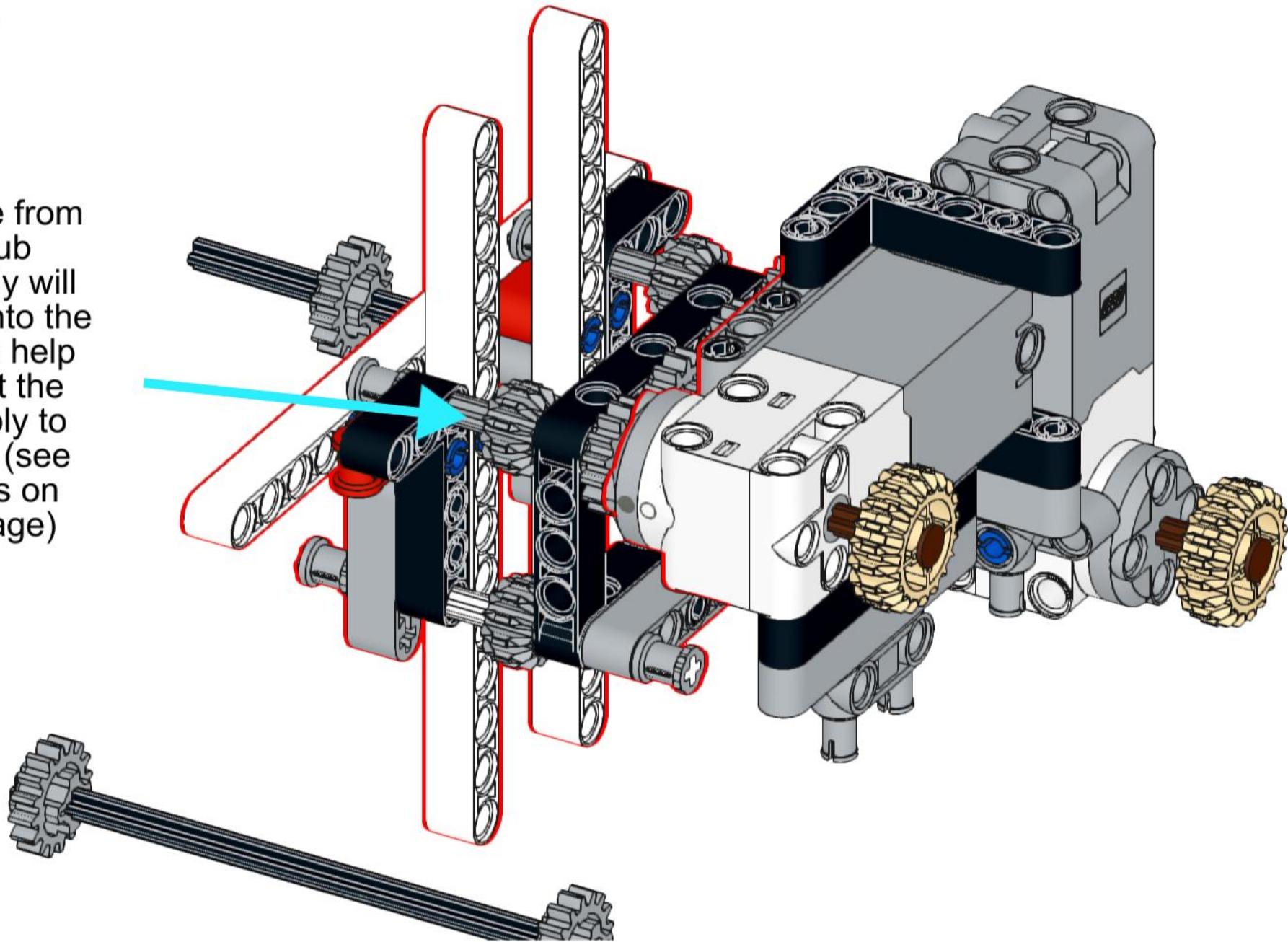


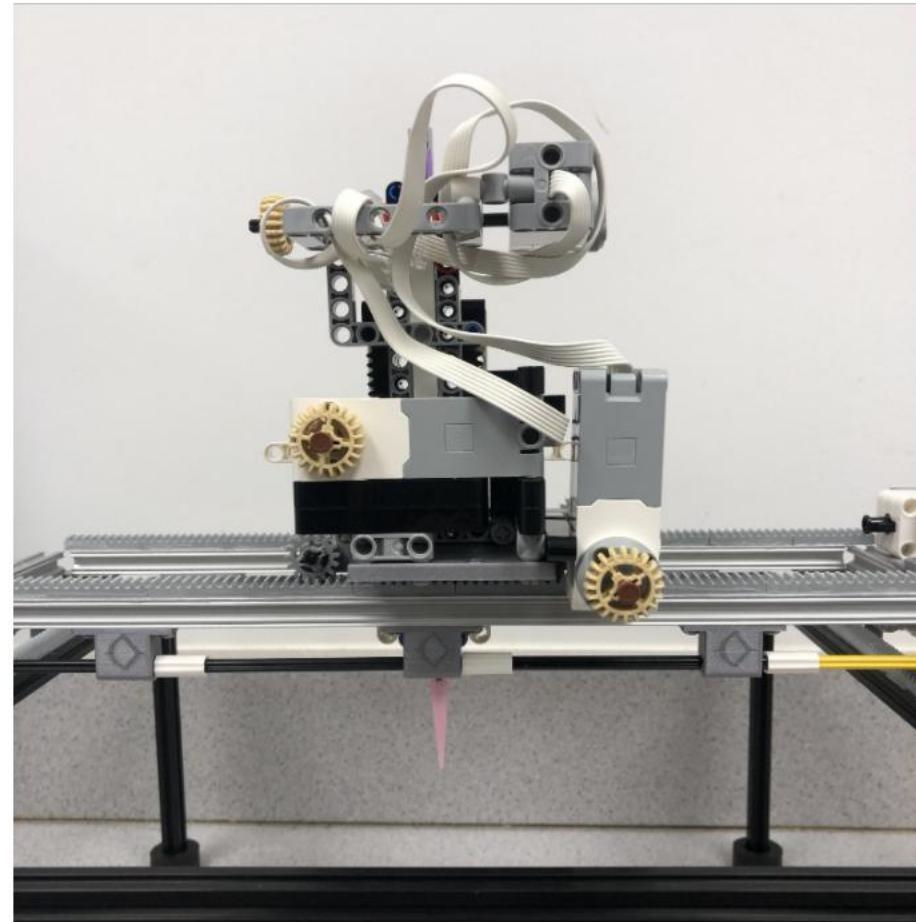
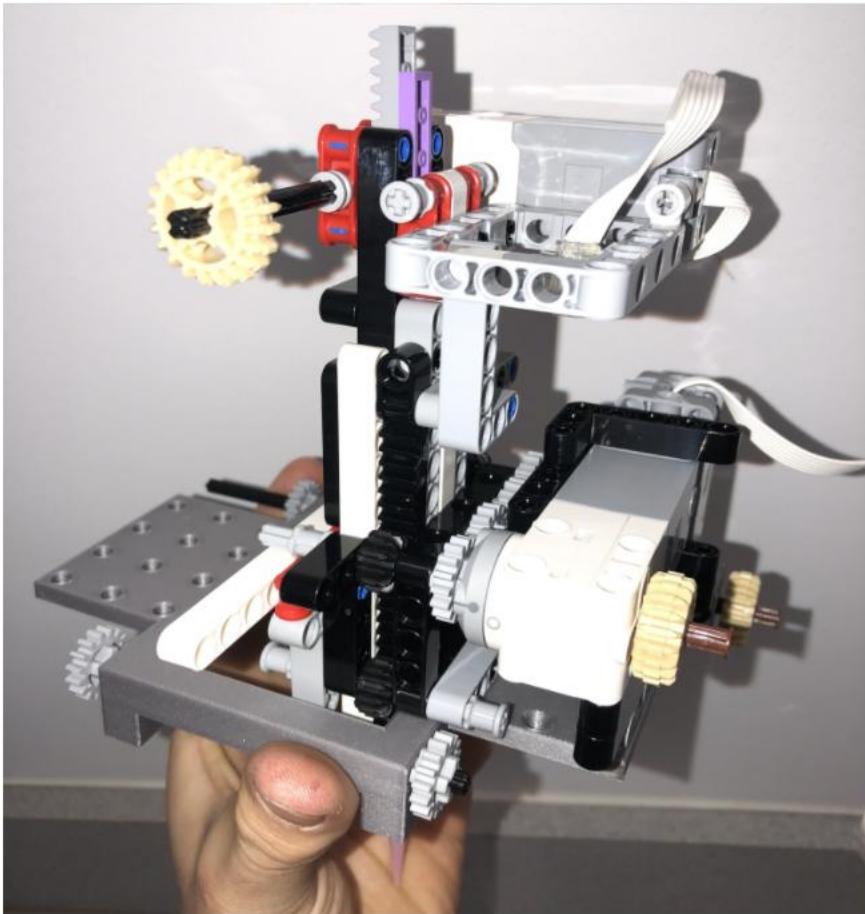
**37**



# 38

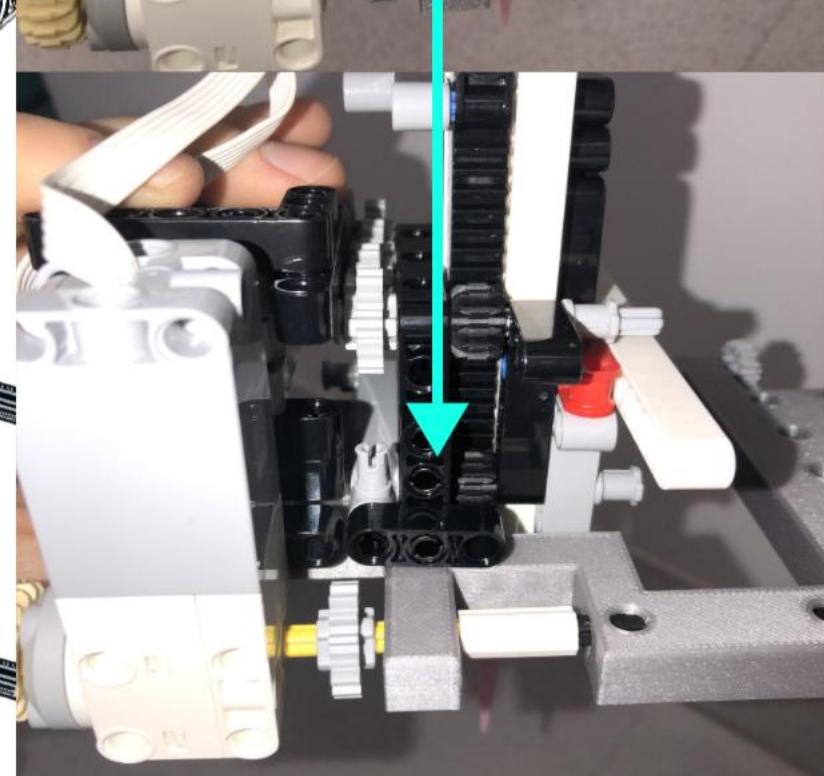
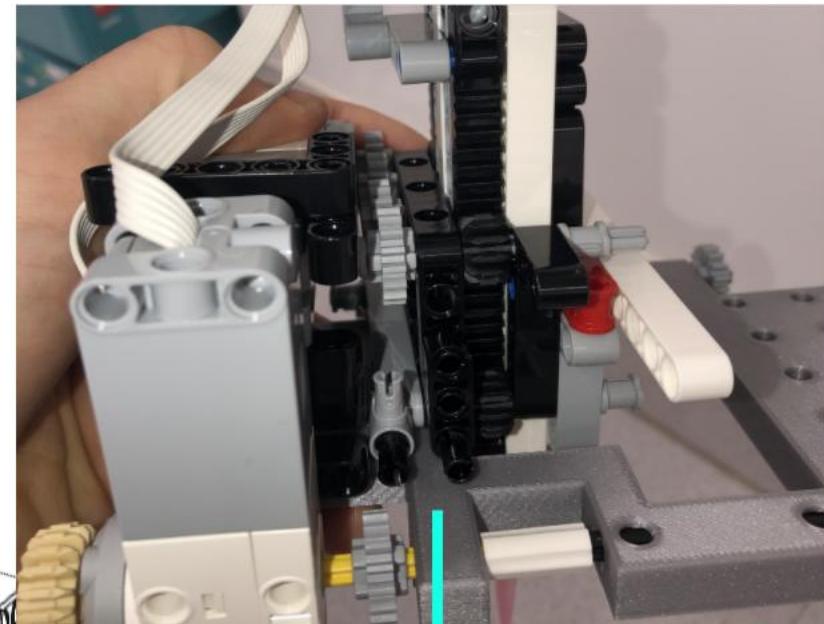
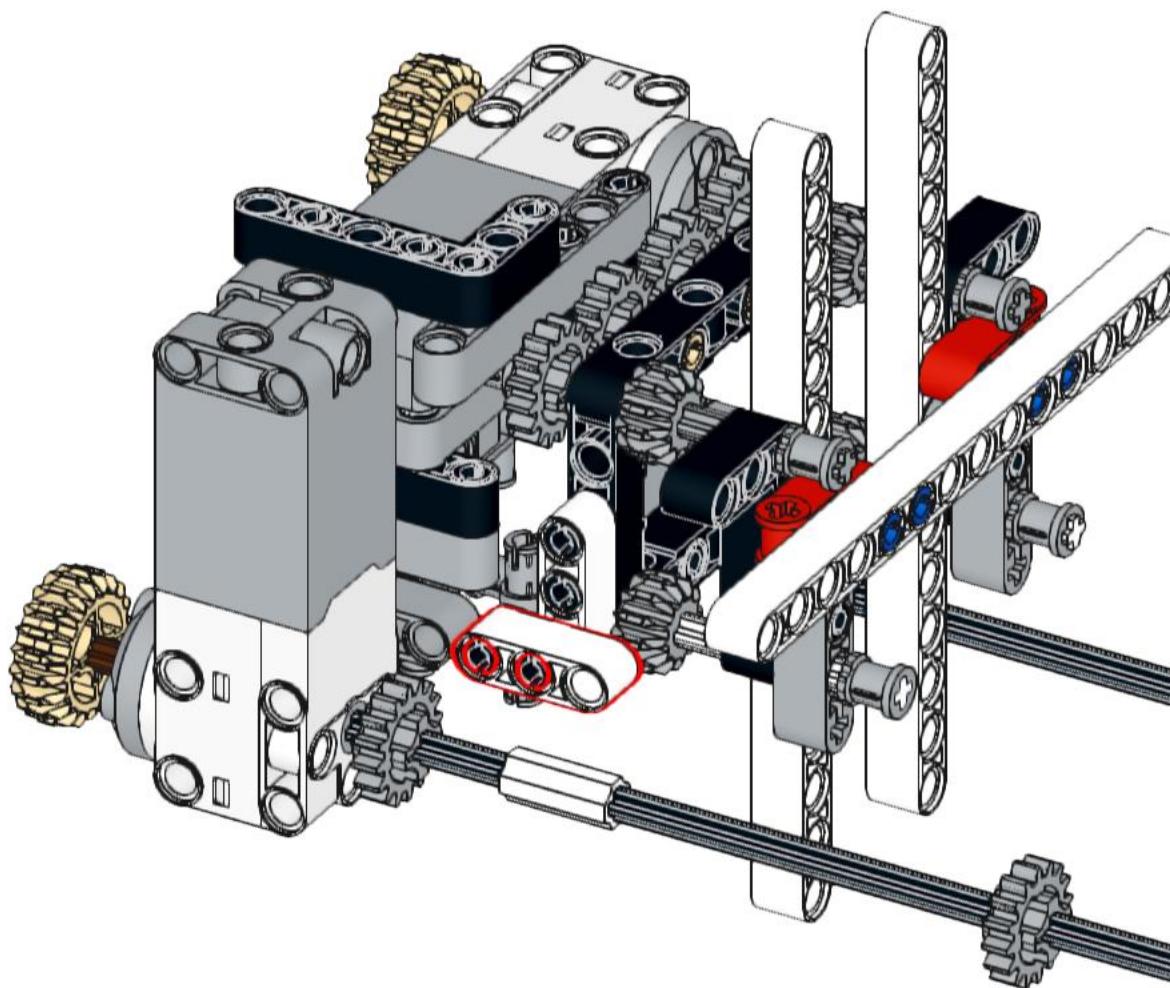
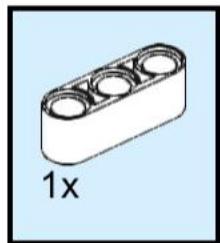
This axle from the sub assembly will now go into the motor to help connect the assembly to the cart (see pictures on next page)



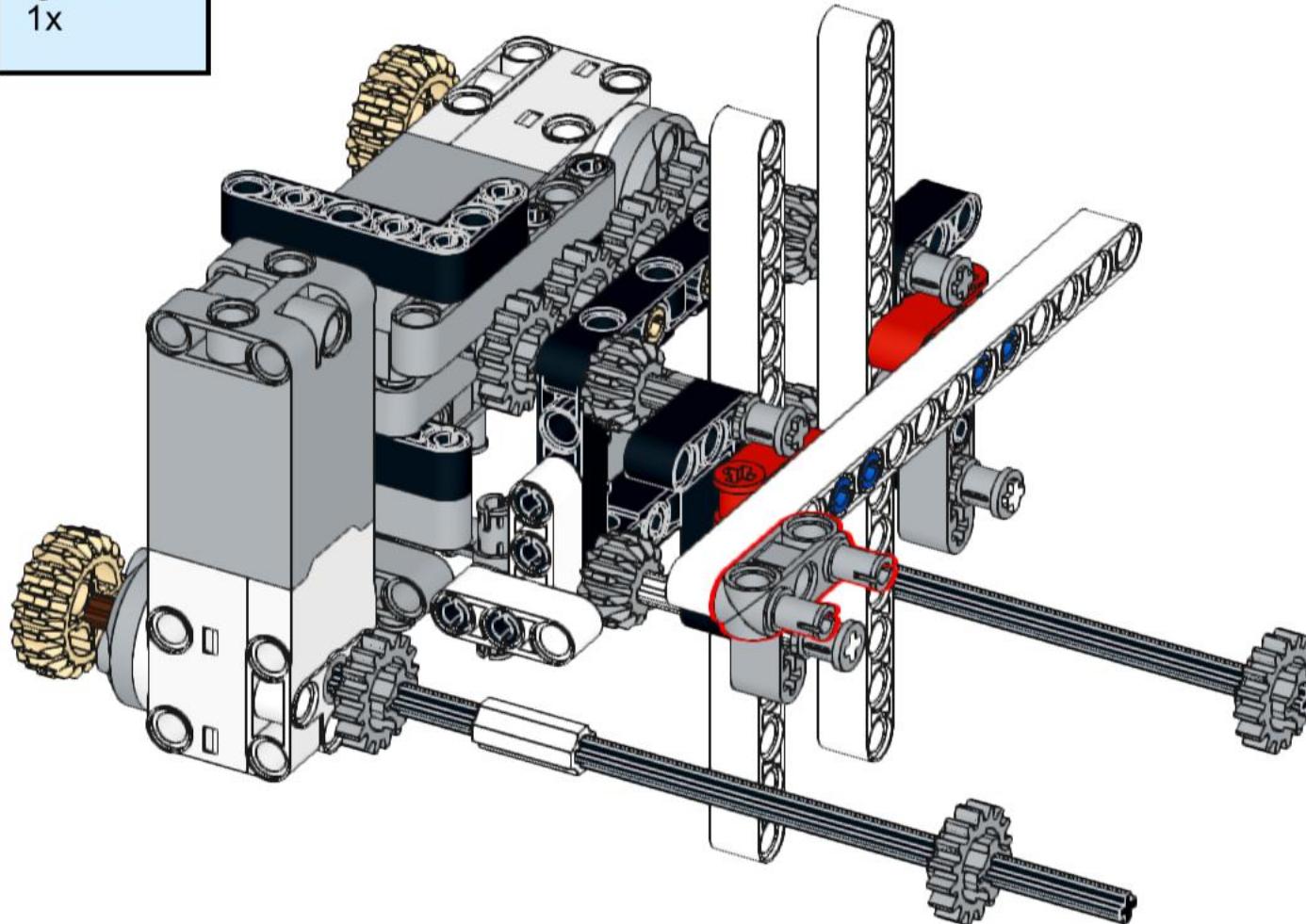
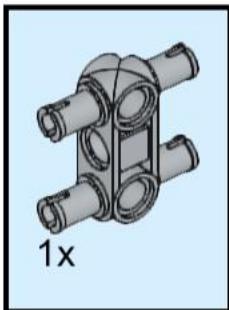


Insert the proper axle into the motor (left) to secure the assembly to the cart base. It may be helpful to place this all on the gantry frame now for further assembly, since the syringe piece is attached.

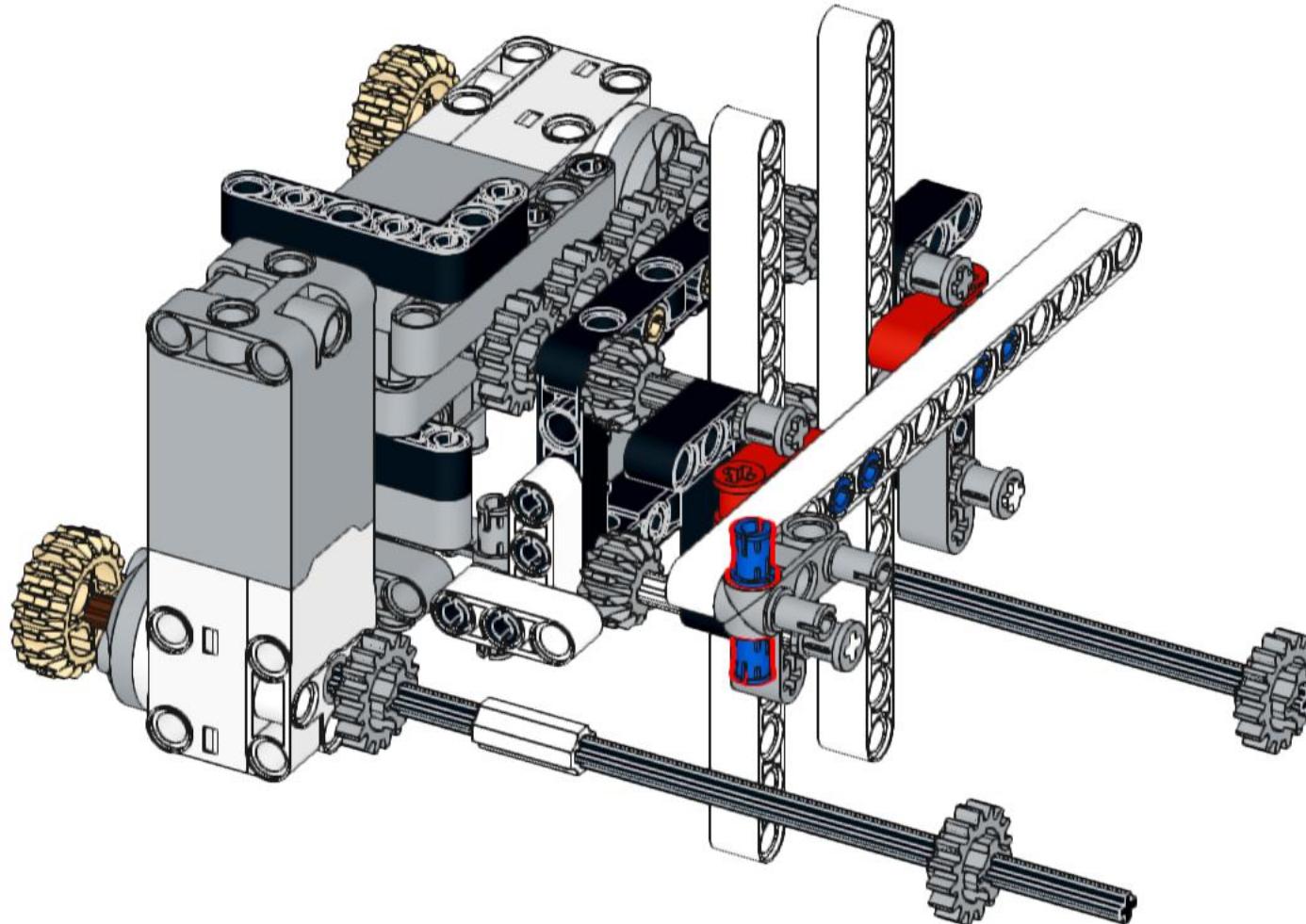
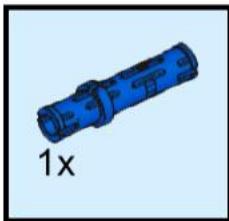
# 39



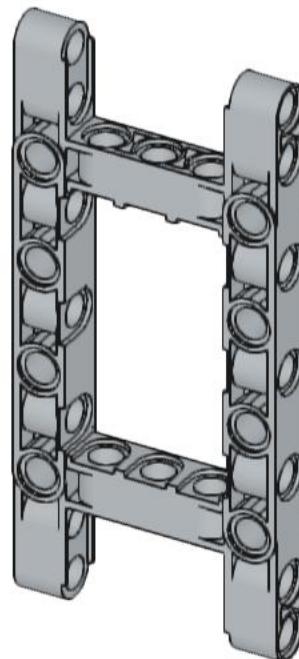
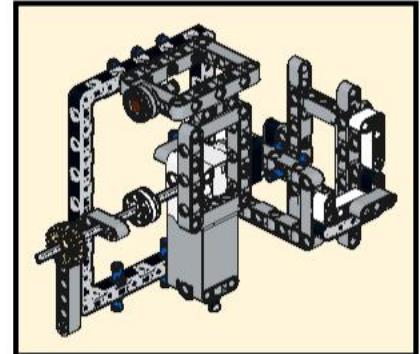
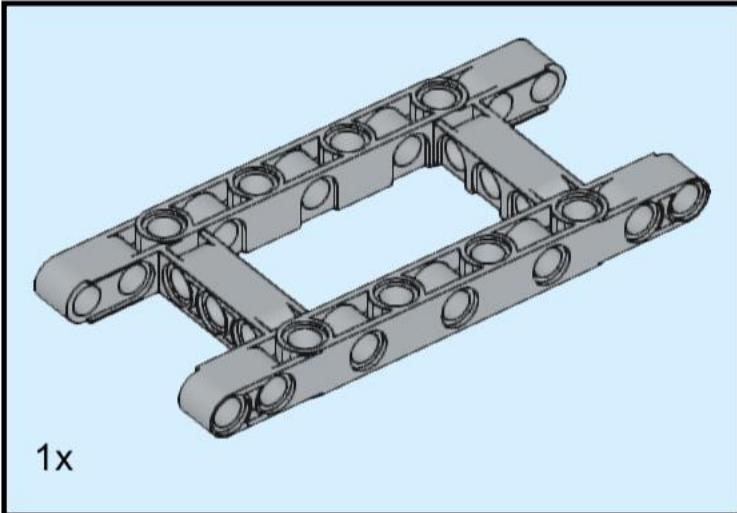
**40**



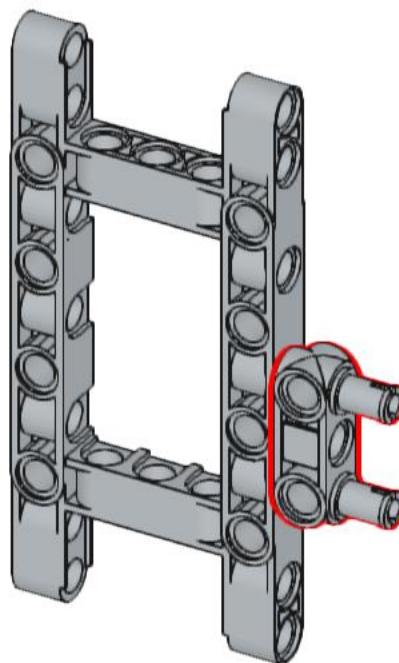
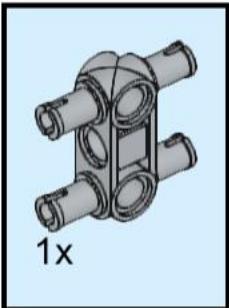
**41**



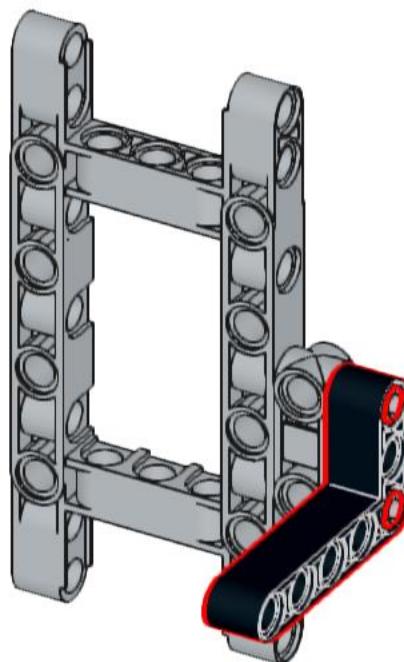
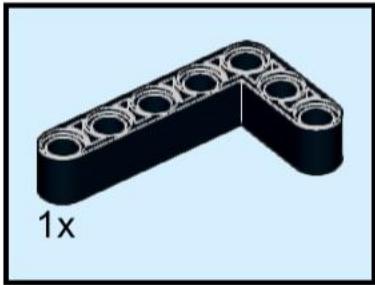
**42**



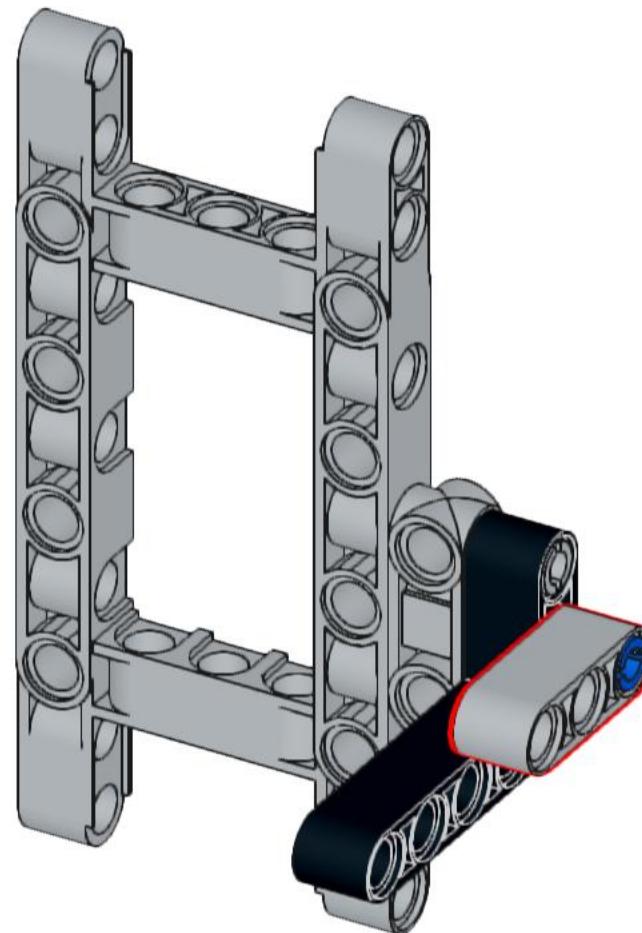
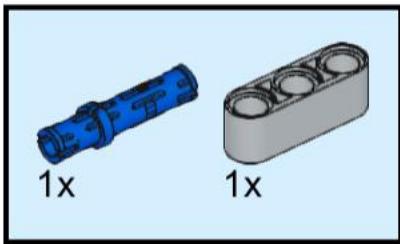
**43**



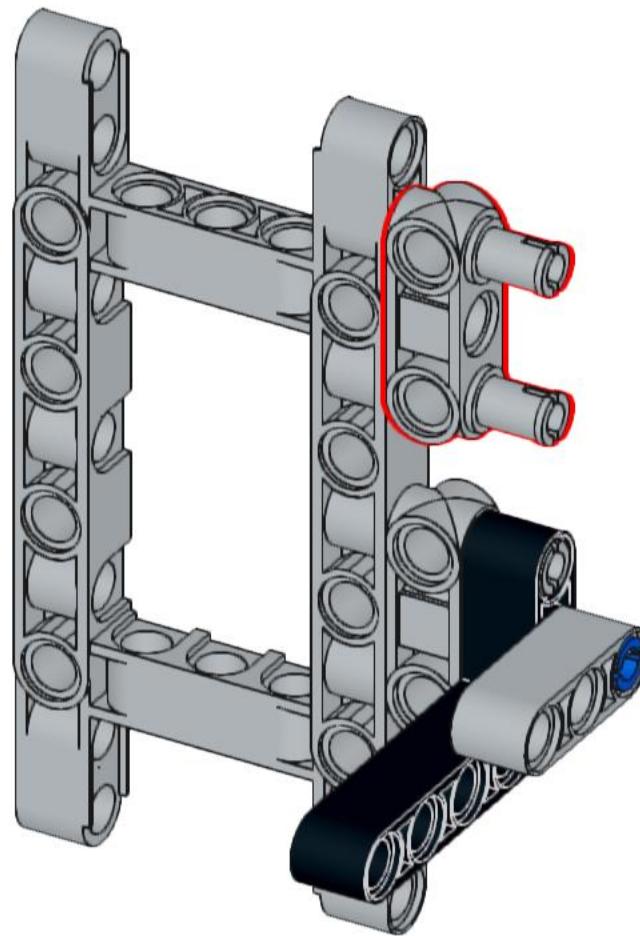
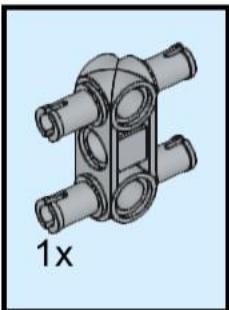
44



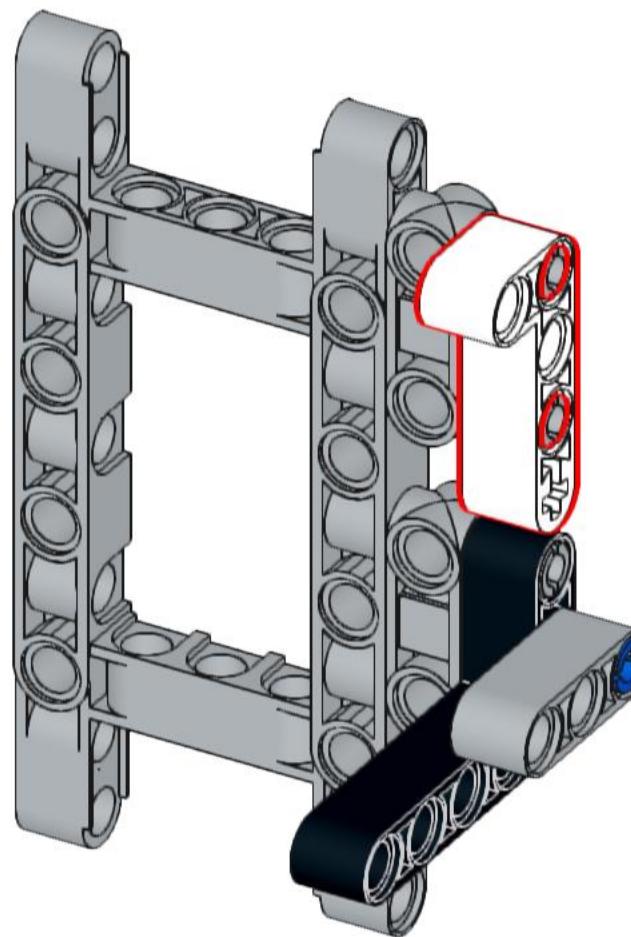
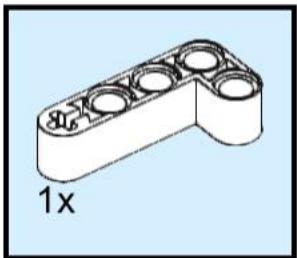
**45**



**46**



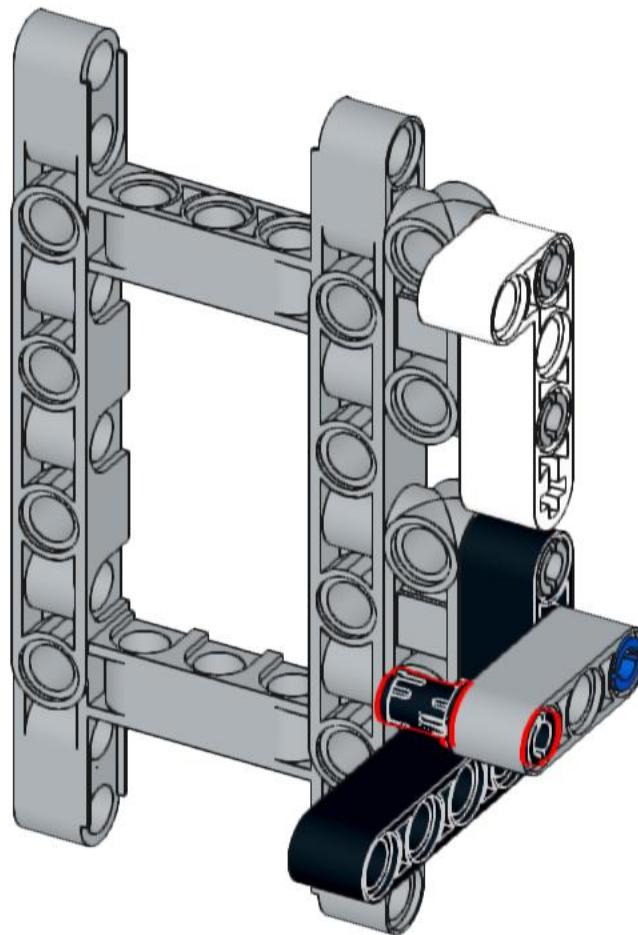
**47**



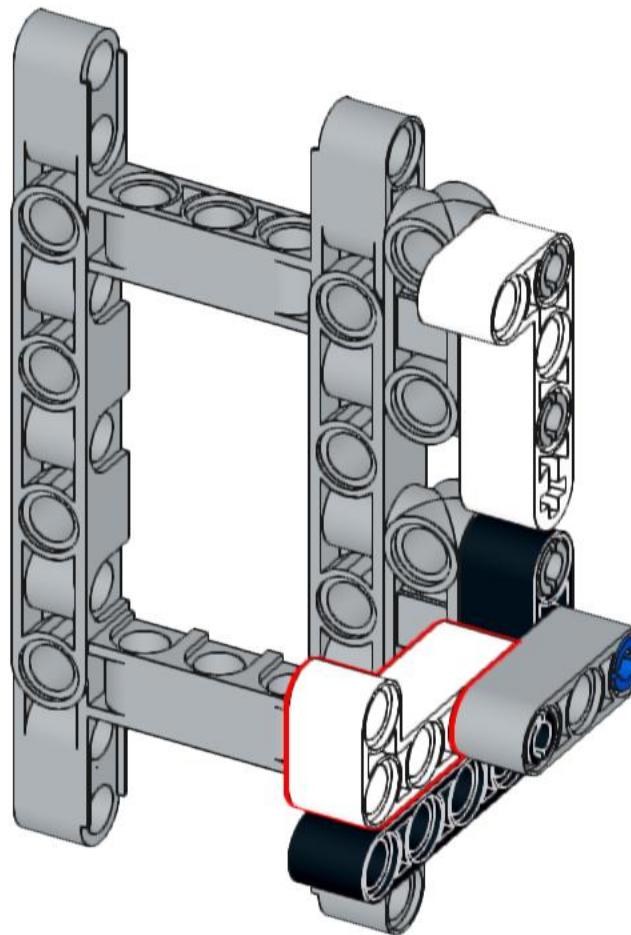
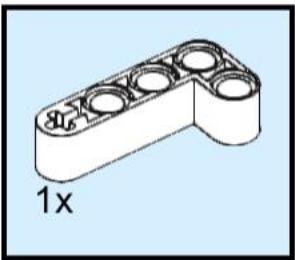
**48**



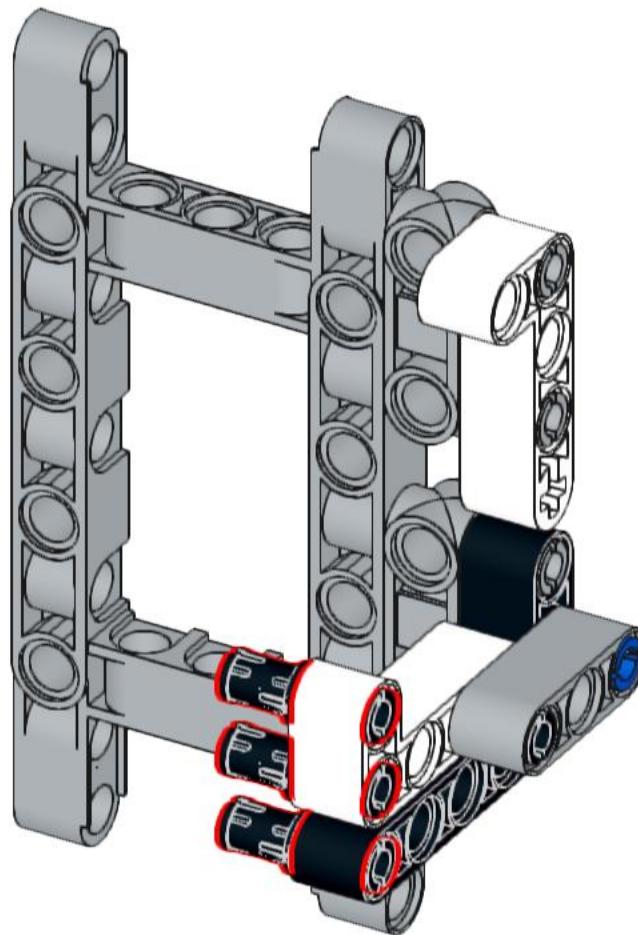
1x



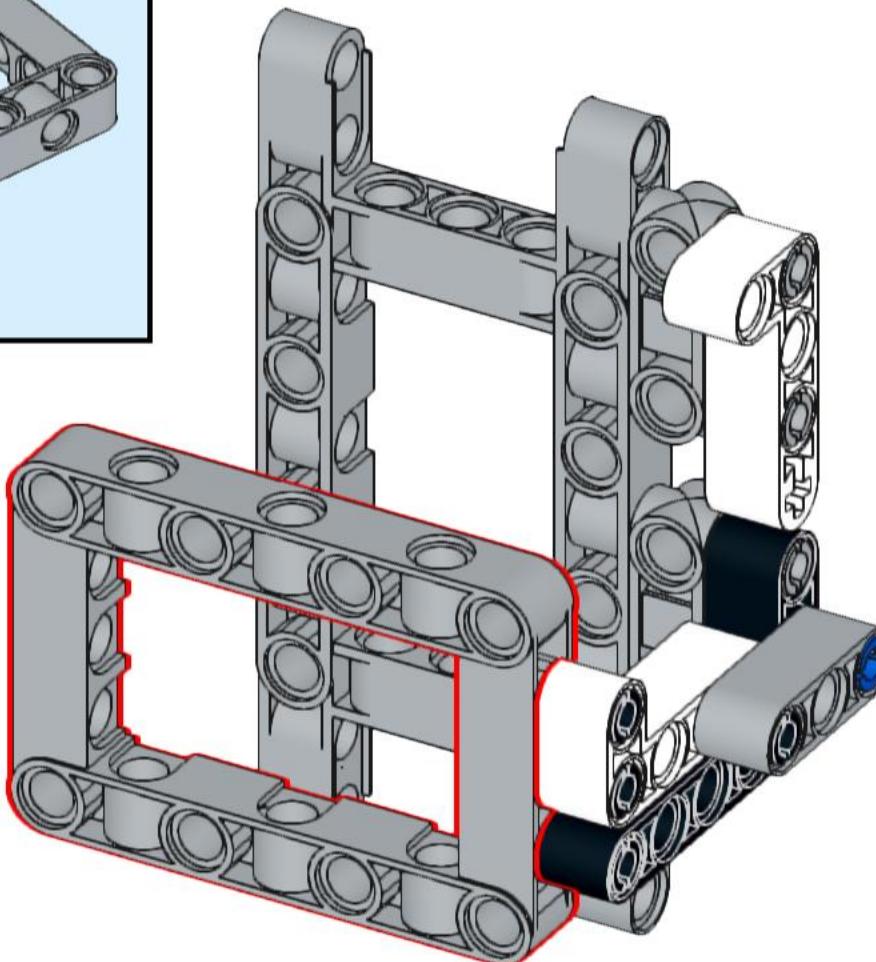
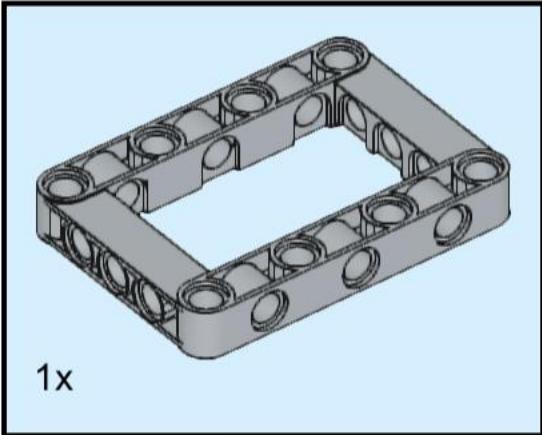
**49**



**50**



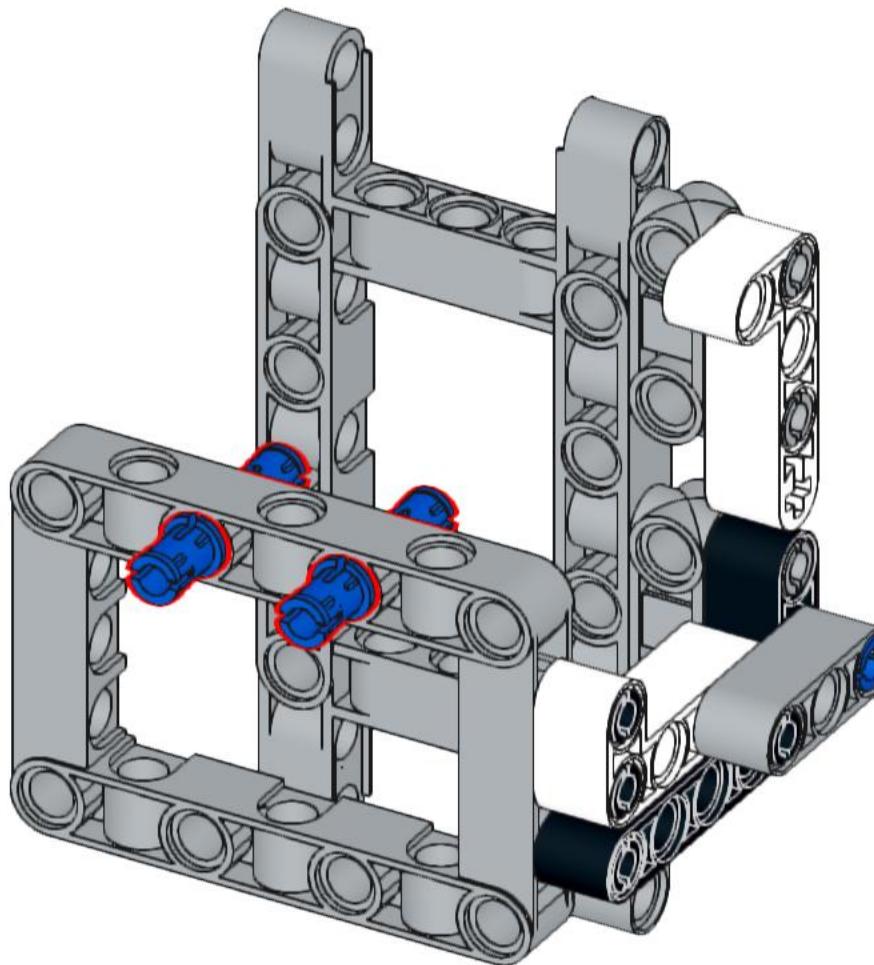
**51**



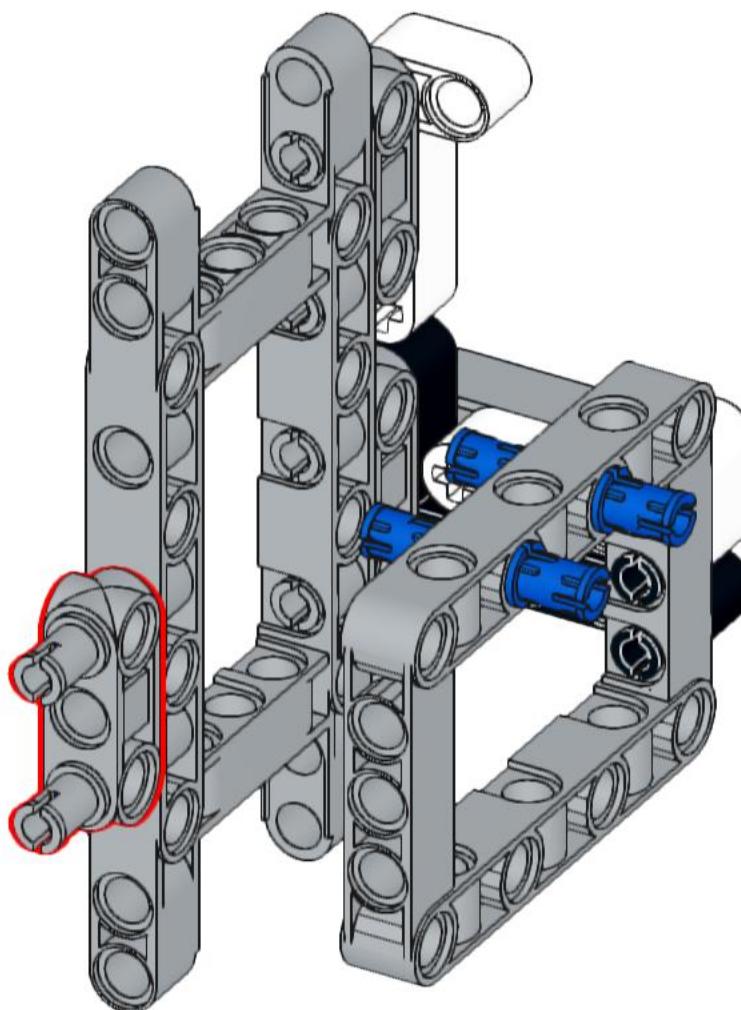
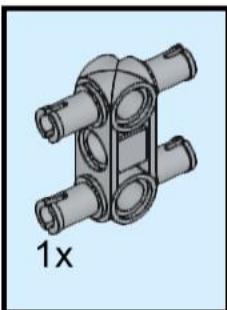
**52**

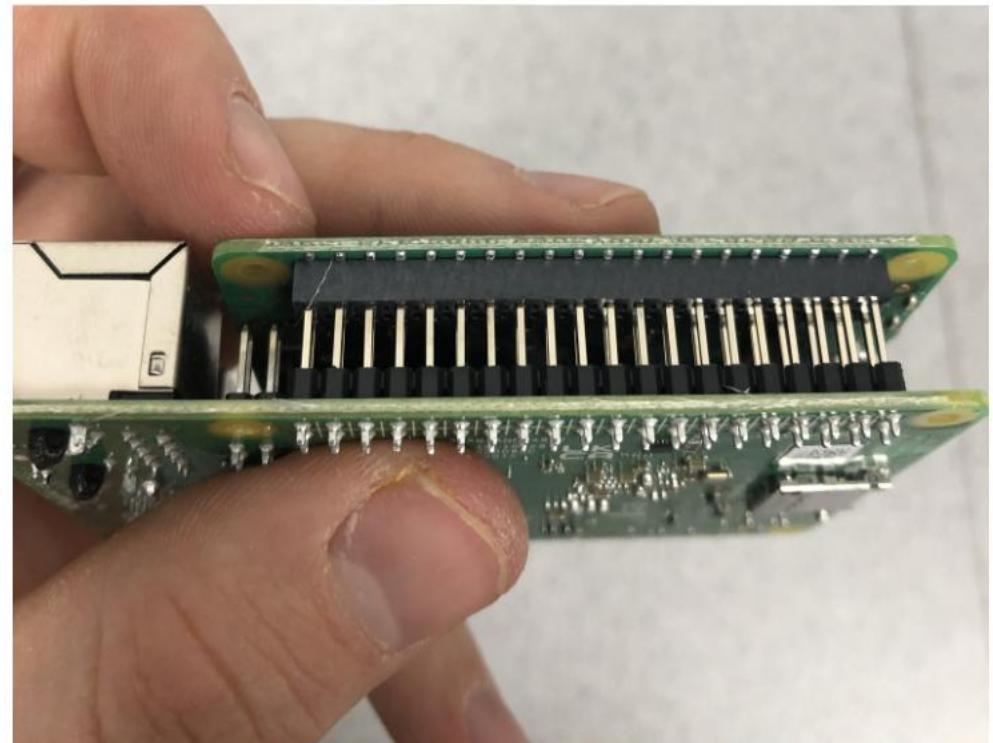
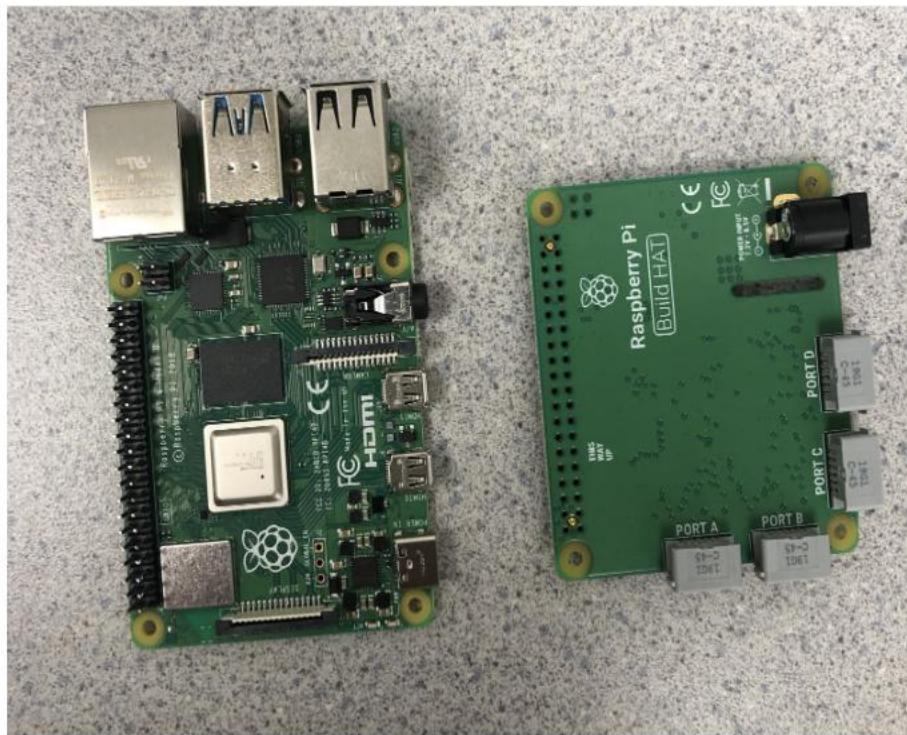


2x



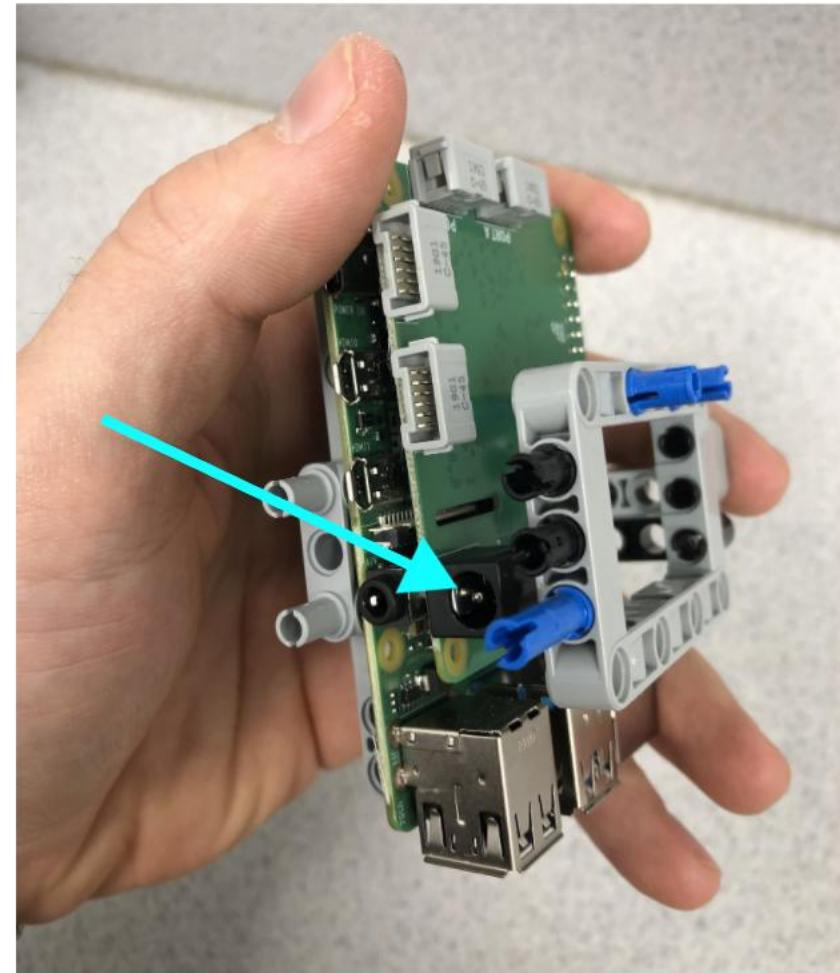
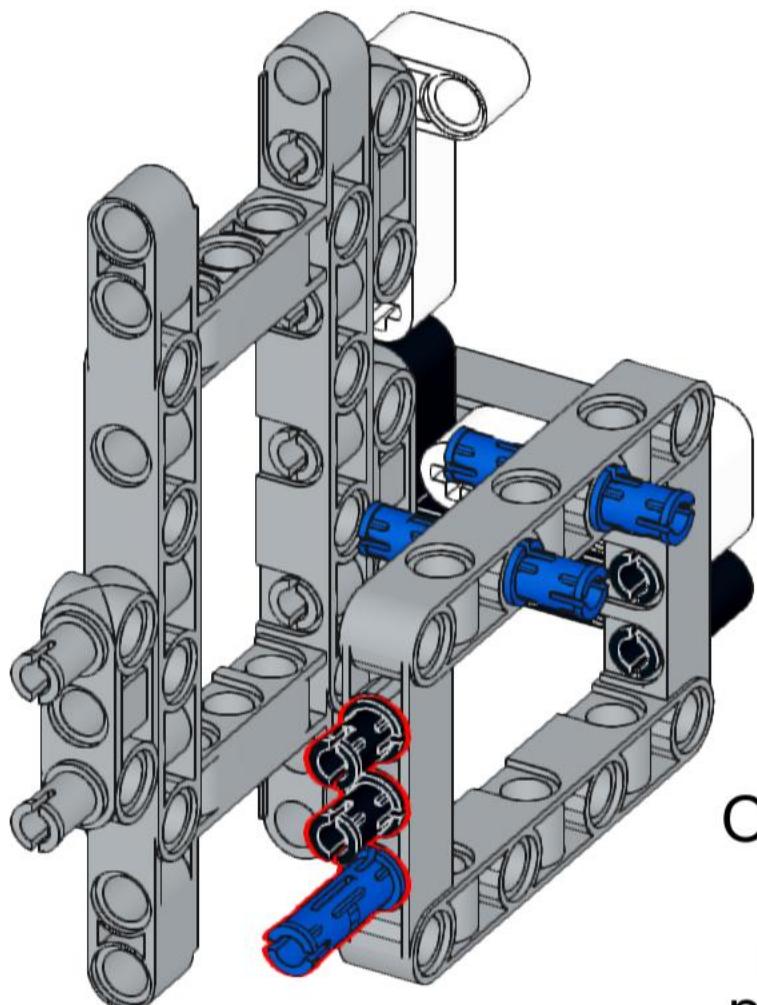
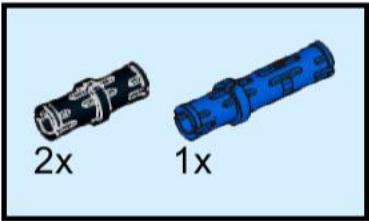
**53**





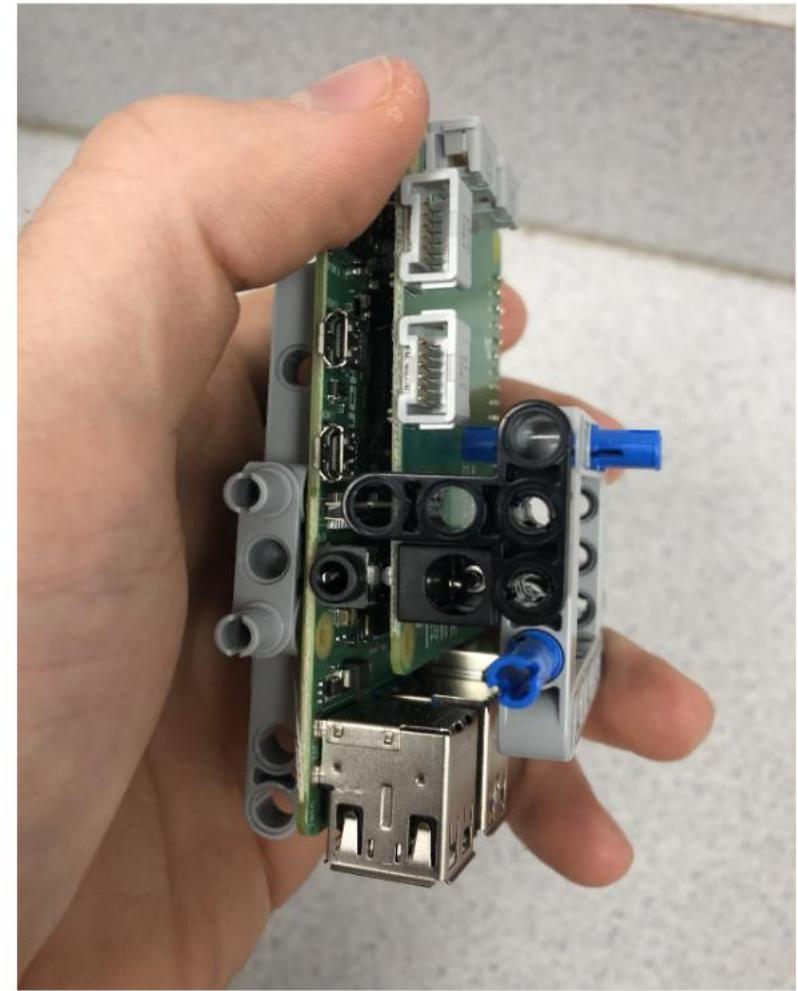
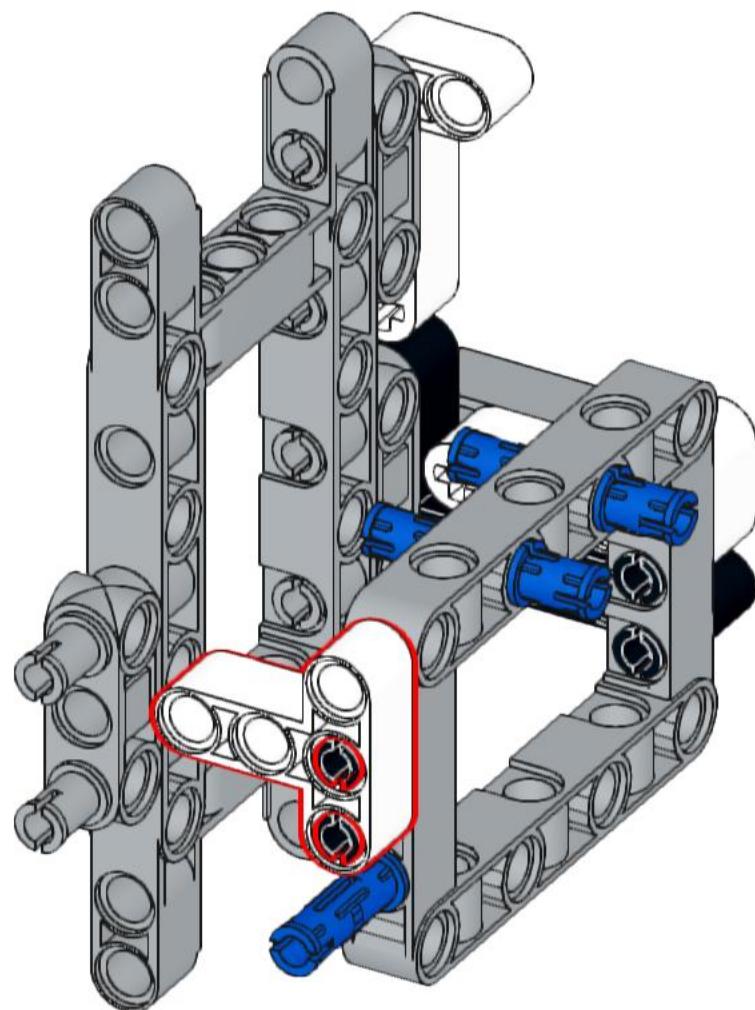
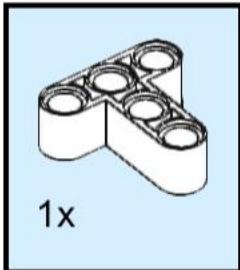
Gather R-Pi and Buildhat, and align pins as shown in the image on the right, then push them all the way in.

# 54



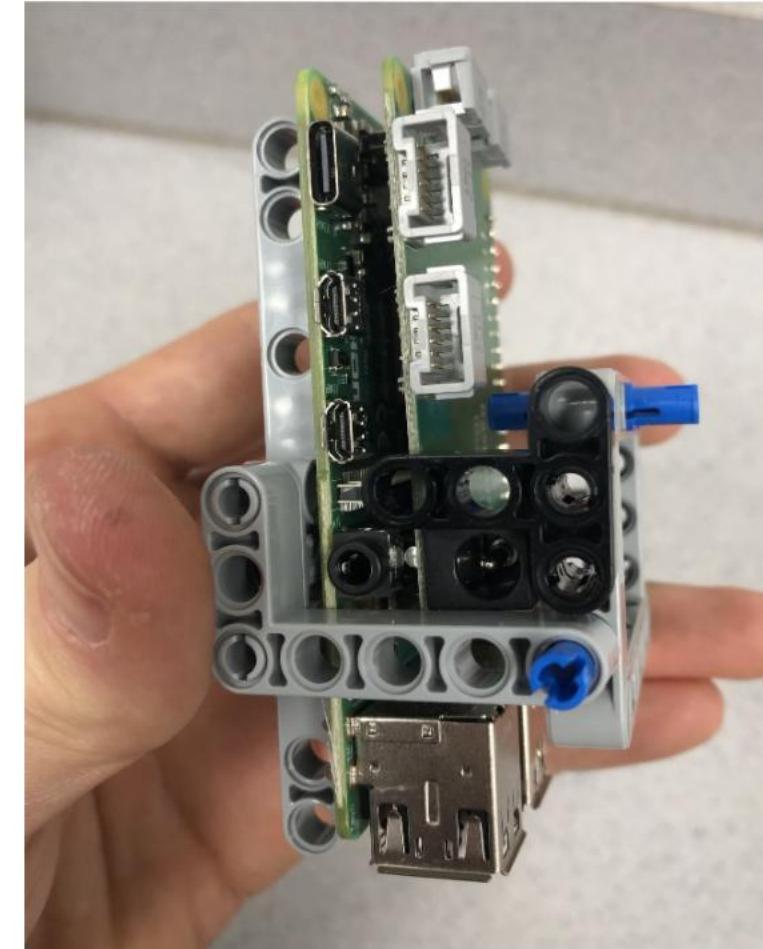
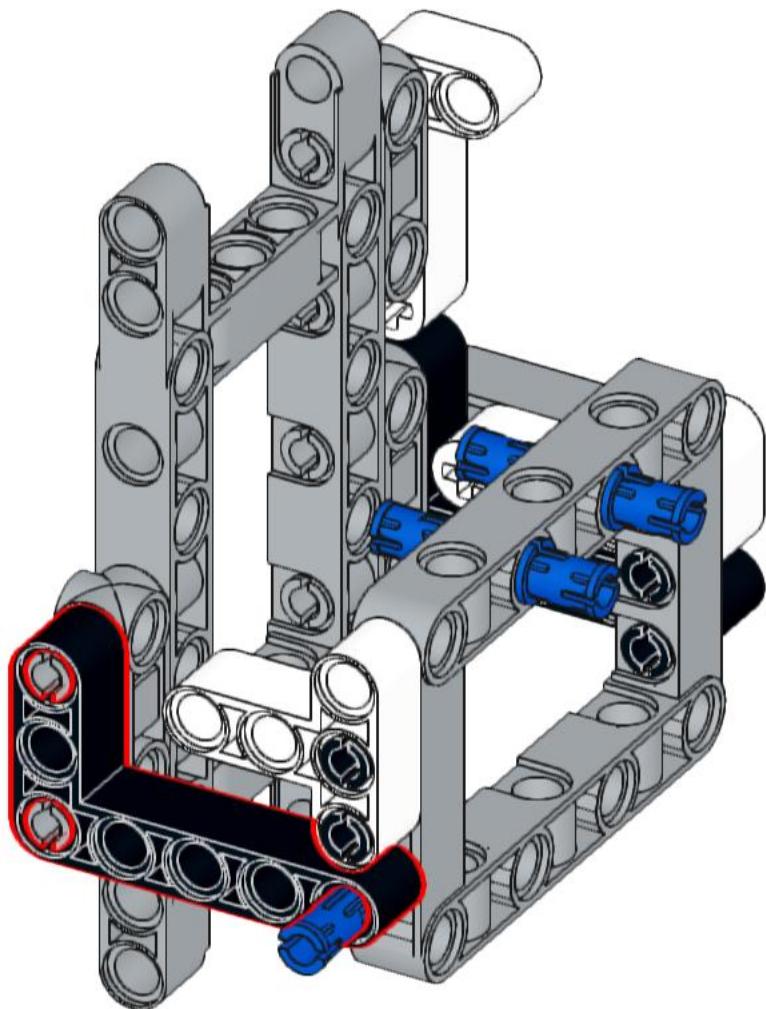
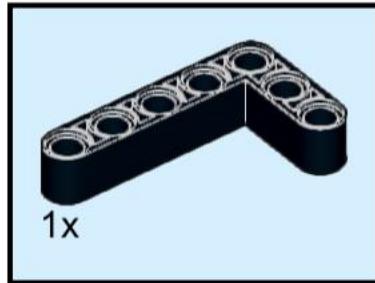
Once the 3 pins are inserted, place the R-Pi + BH in the assembly with the orientation shown here, so the black power supply (arrow), is near the pins.

# 55



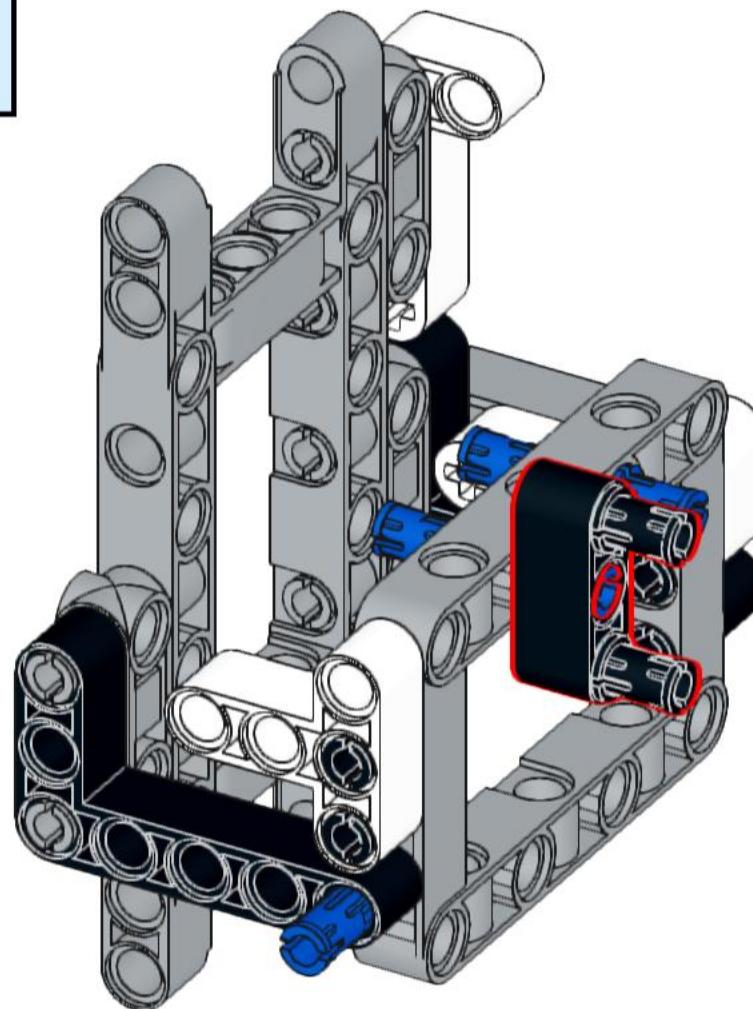
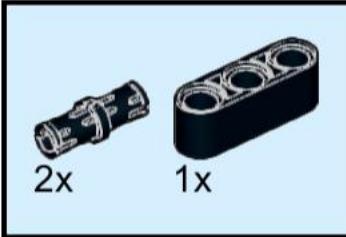
Insert the T-shaped piece and press the top of the flat edge of the power supply against it

# 56

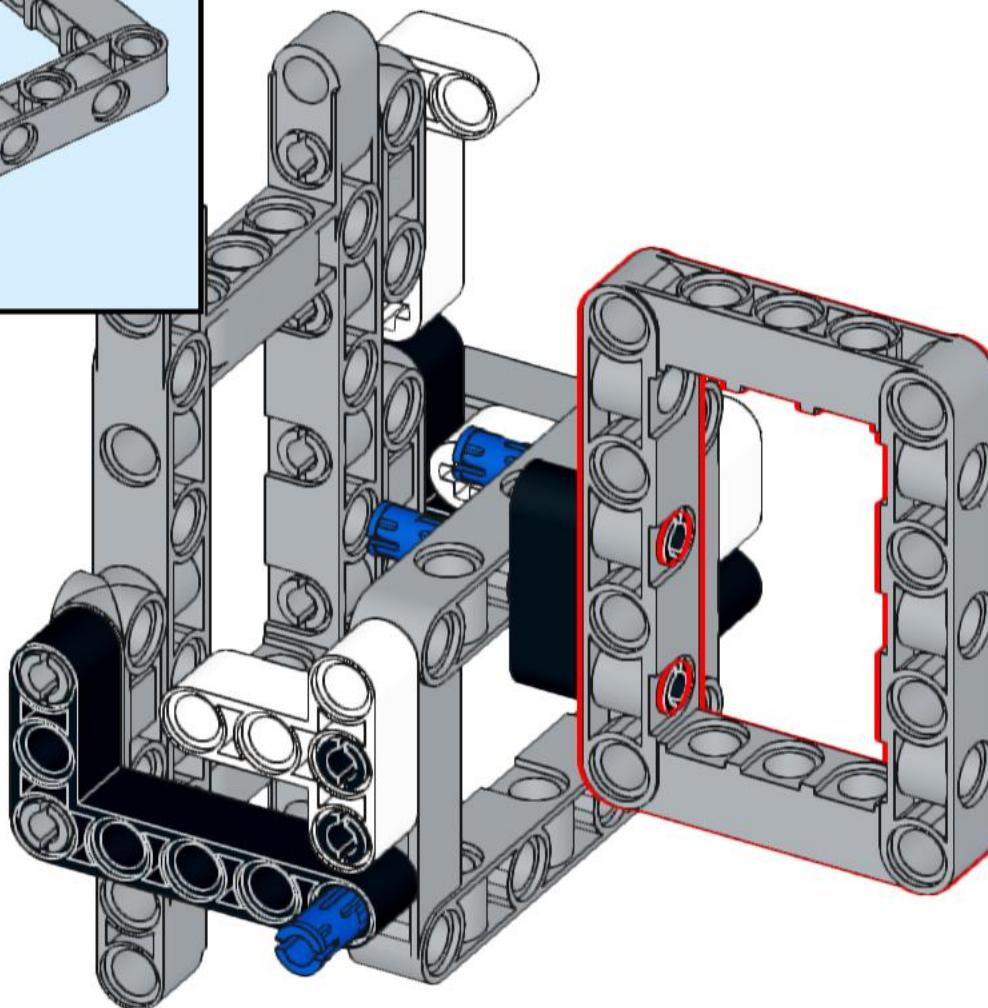
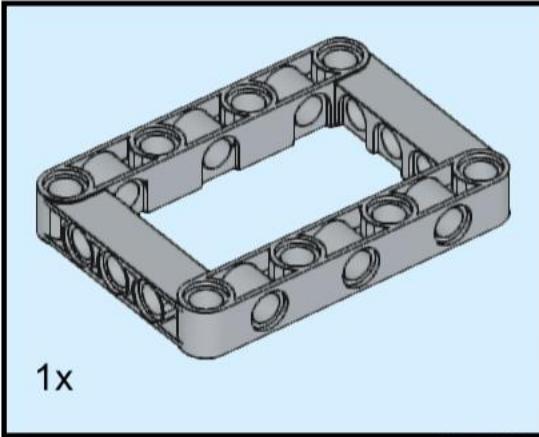


Insert the L-shaped piece so that it pushes up against the bottom flat edge of the power supply box, thereby wedging it in. The R-Pi + BH should be secure enough that it does not need to be held in place anymore

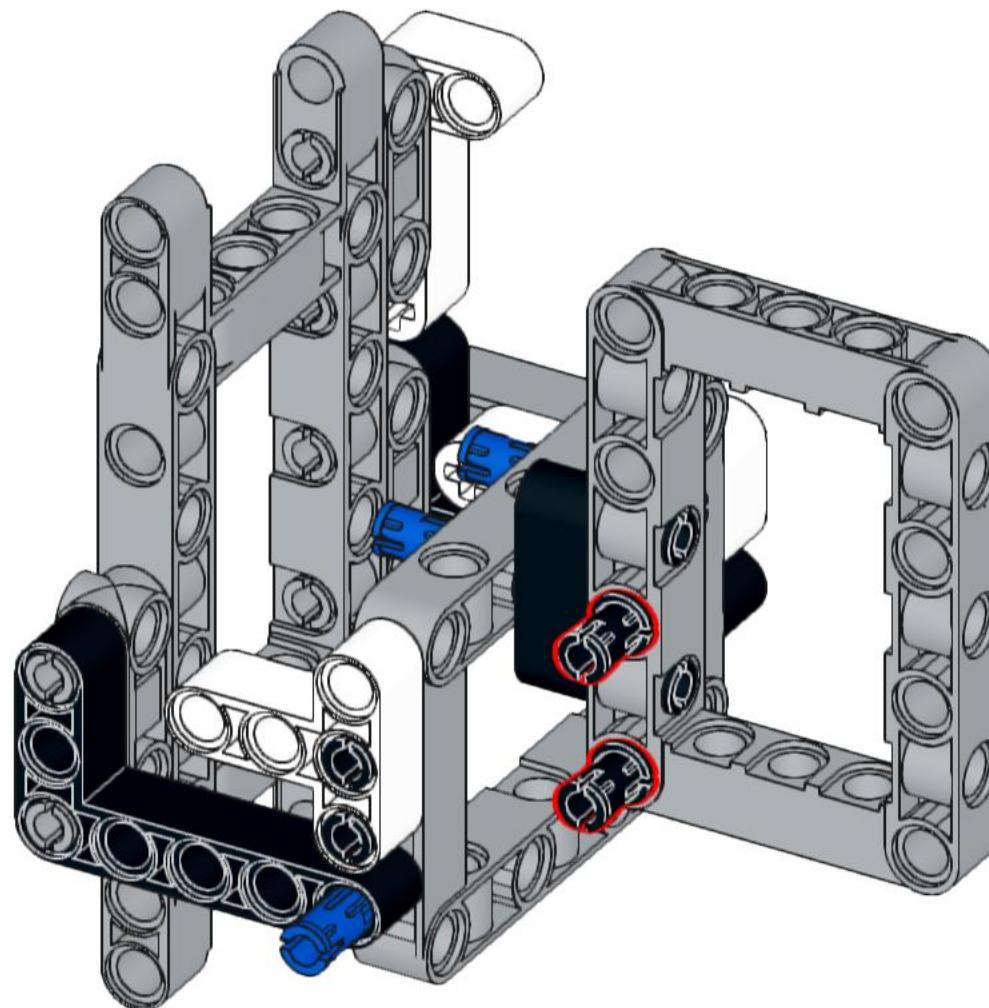
**57**



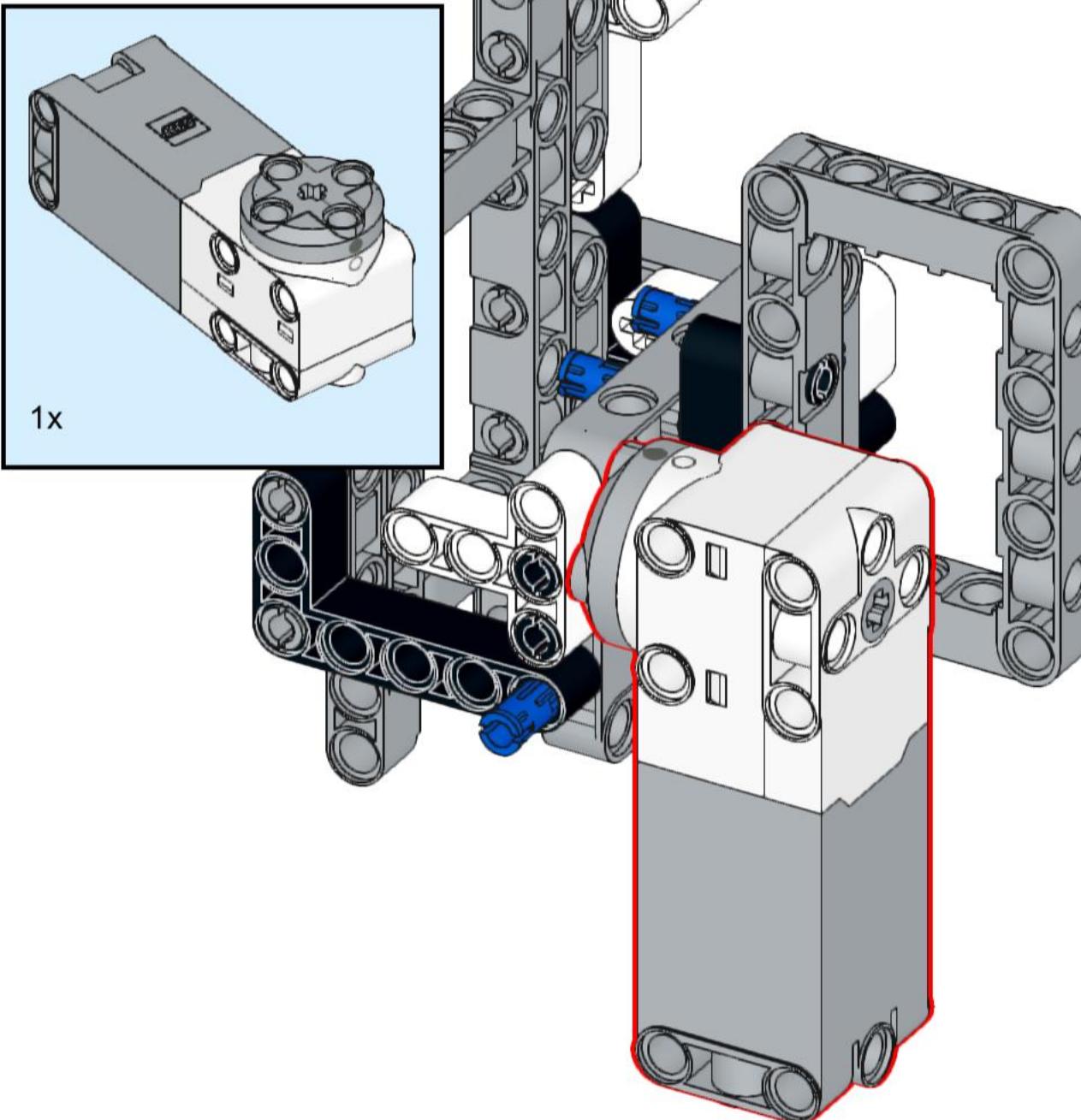
**58**



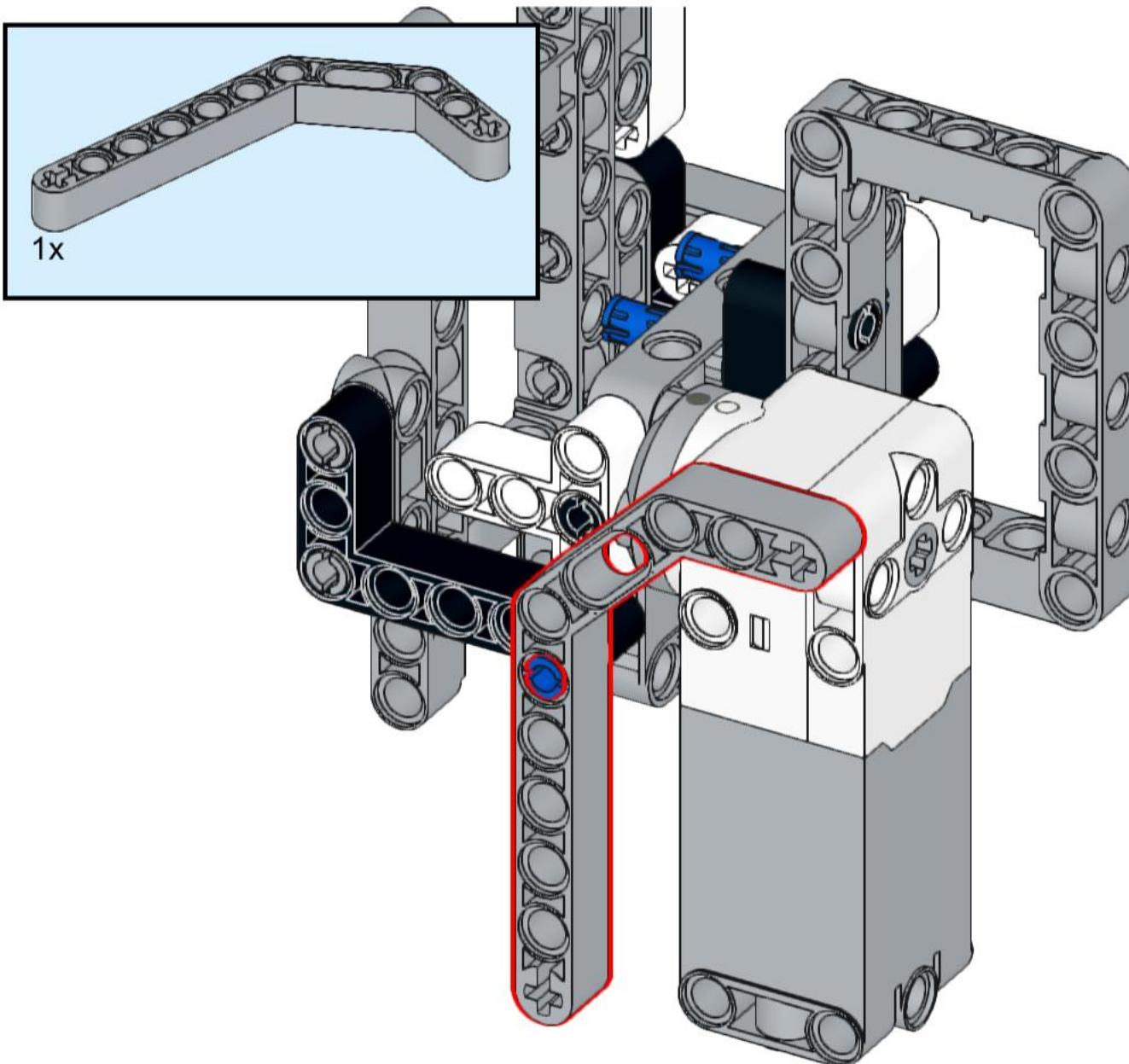
**59**



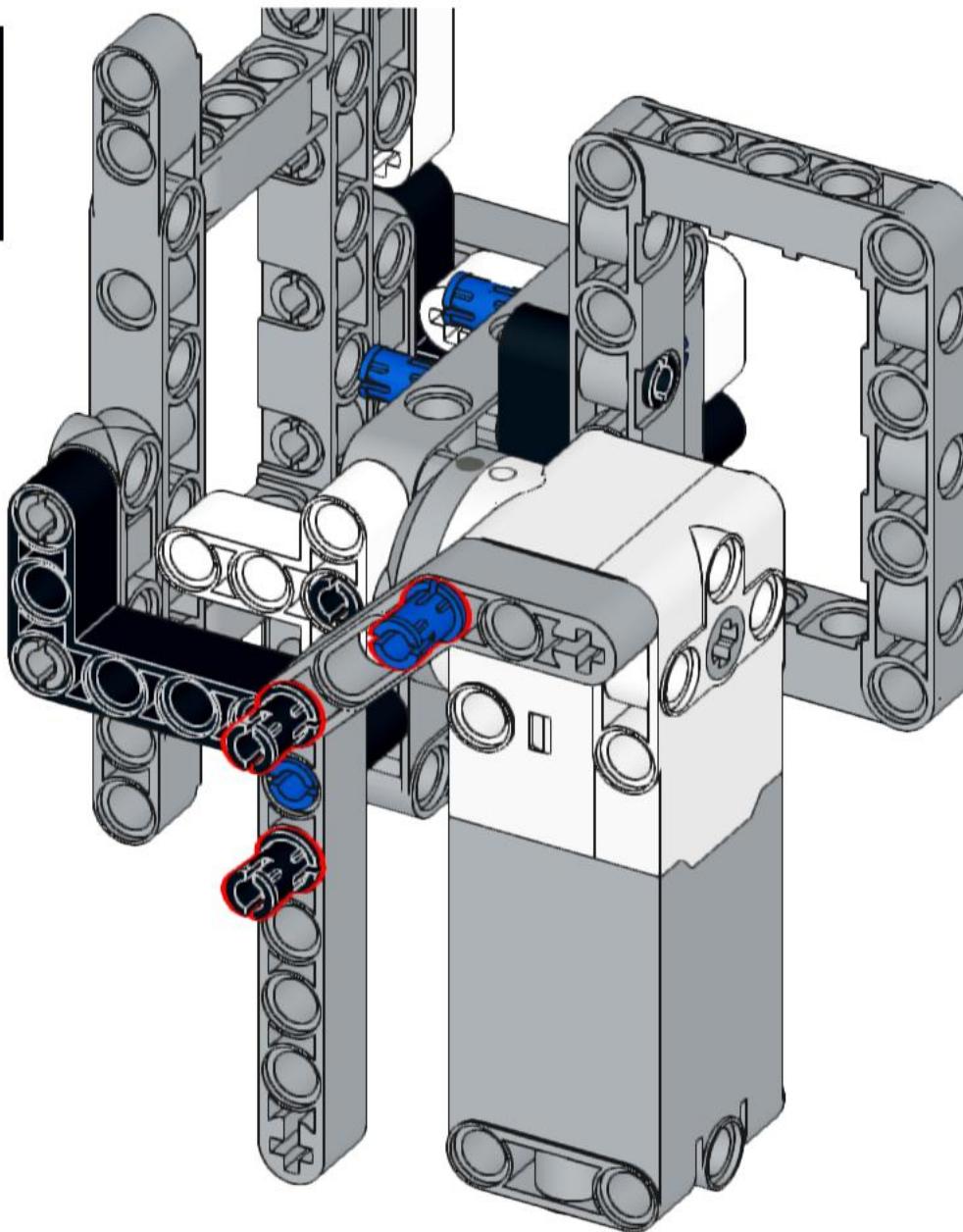
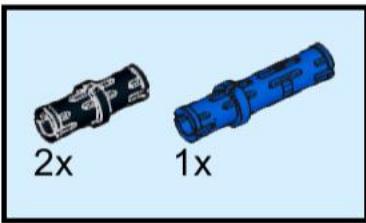
**60**



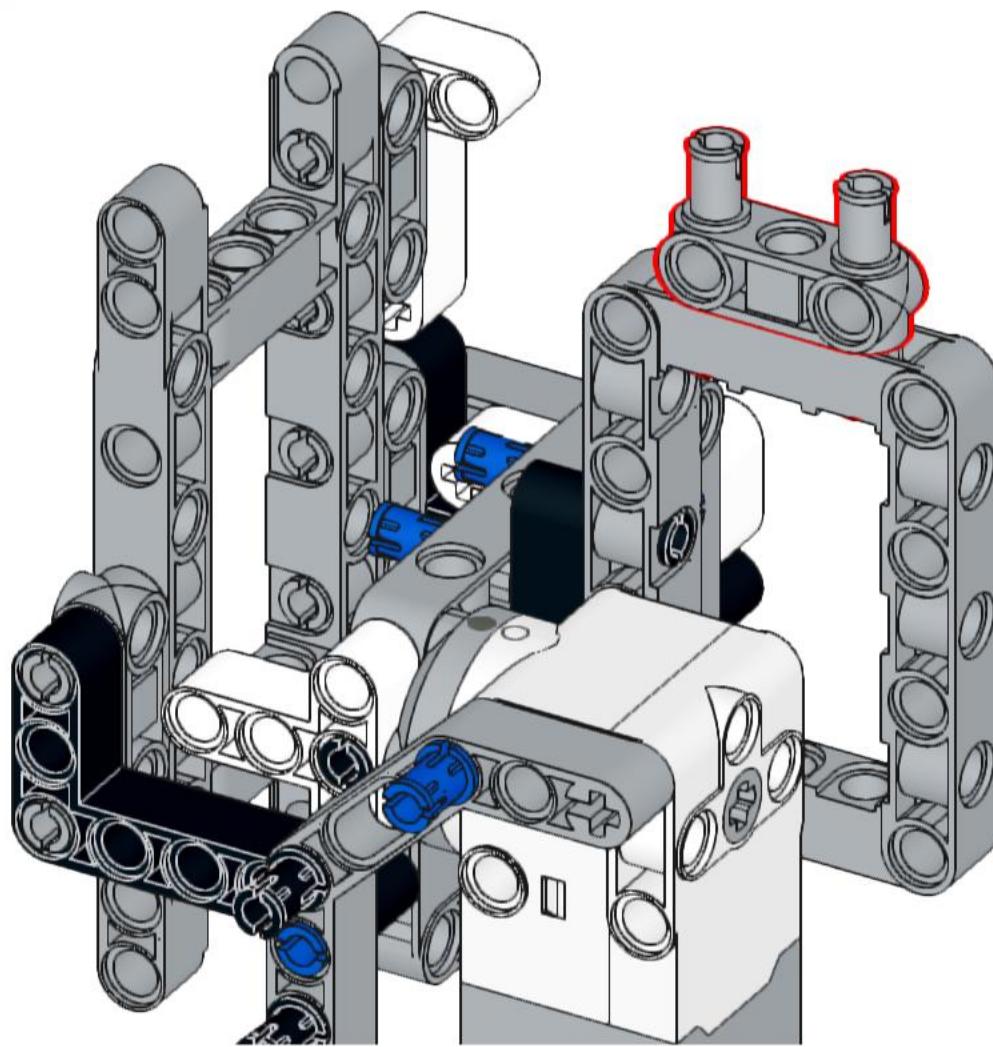
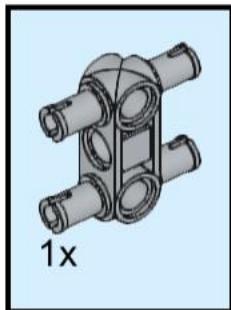
**61**



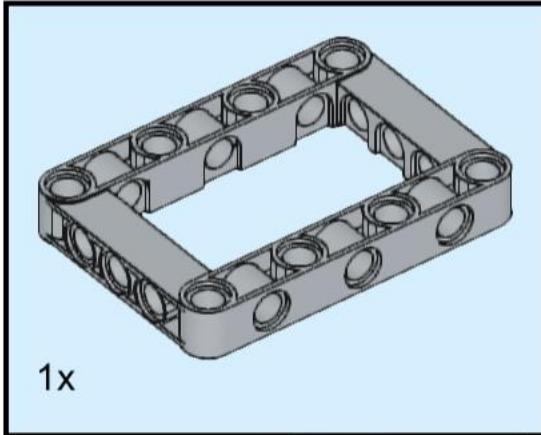
**62**



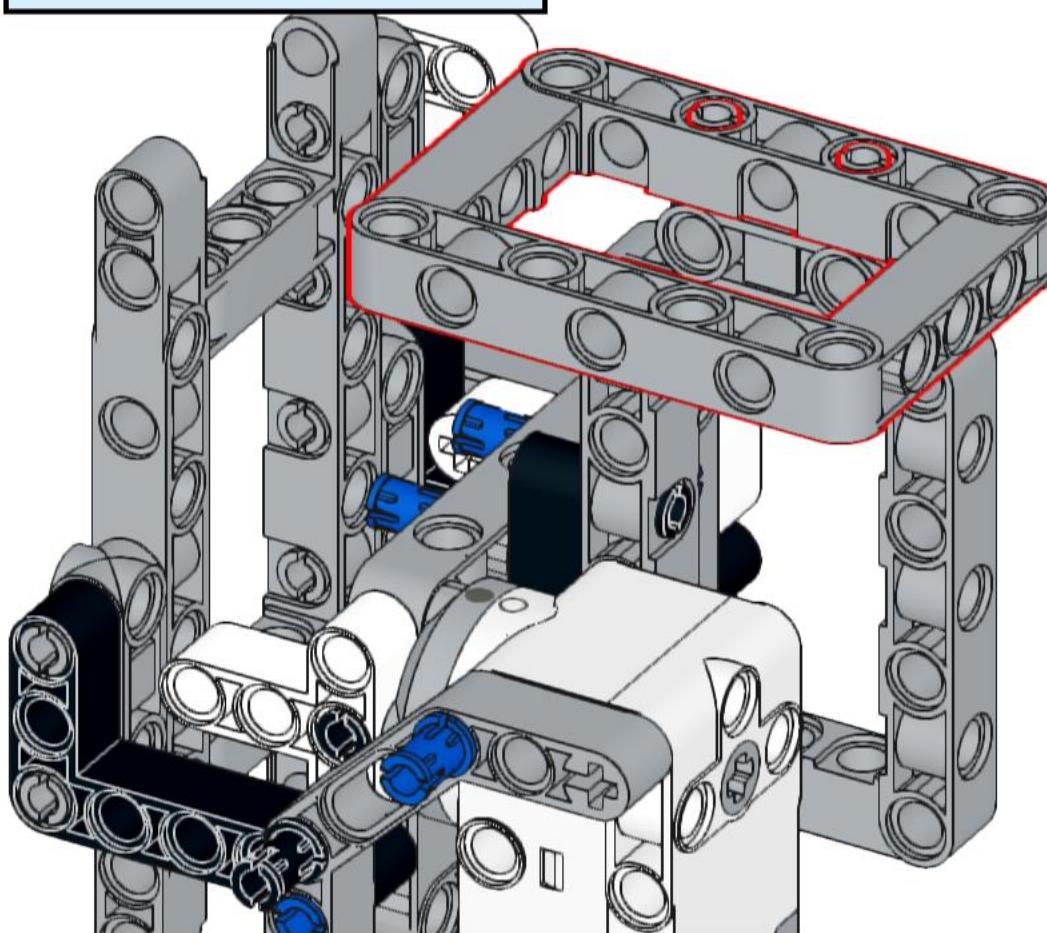
**63**



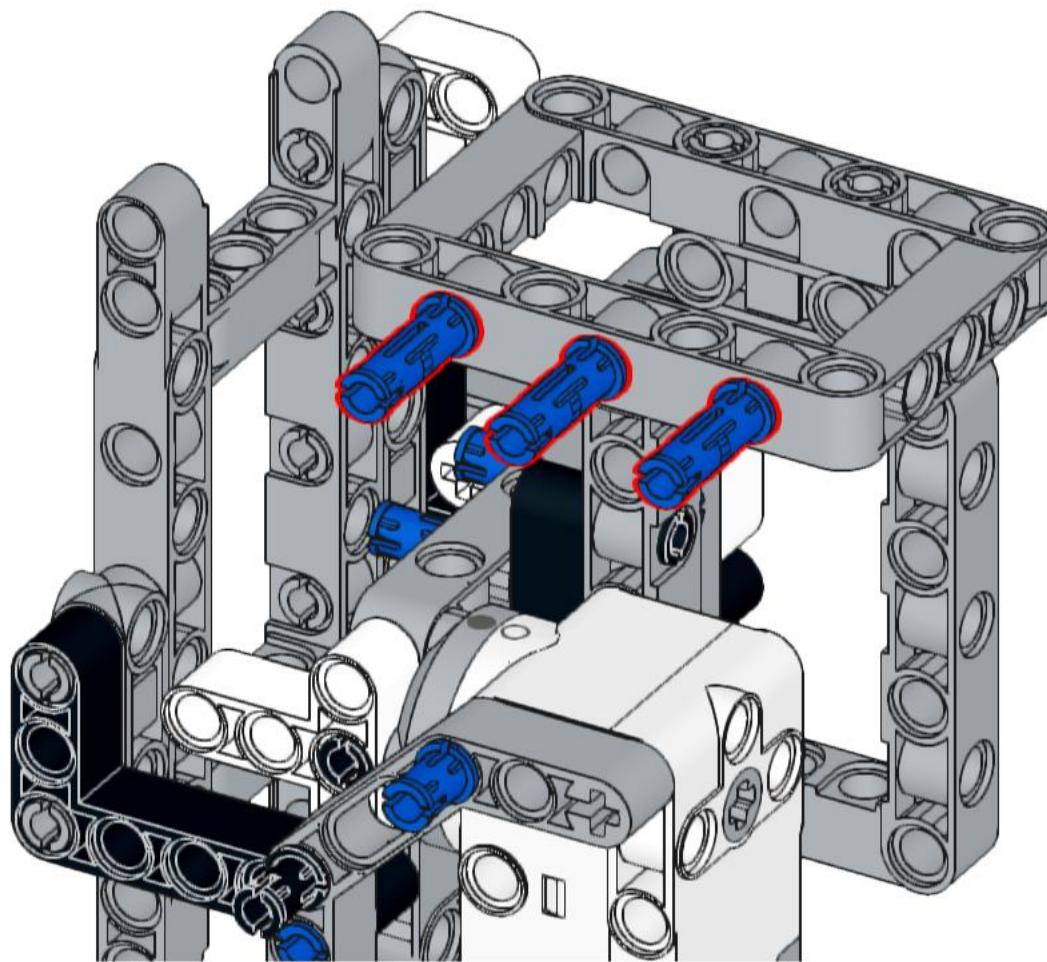
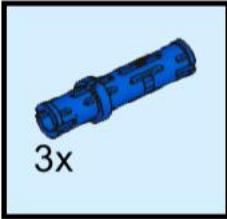
**64**



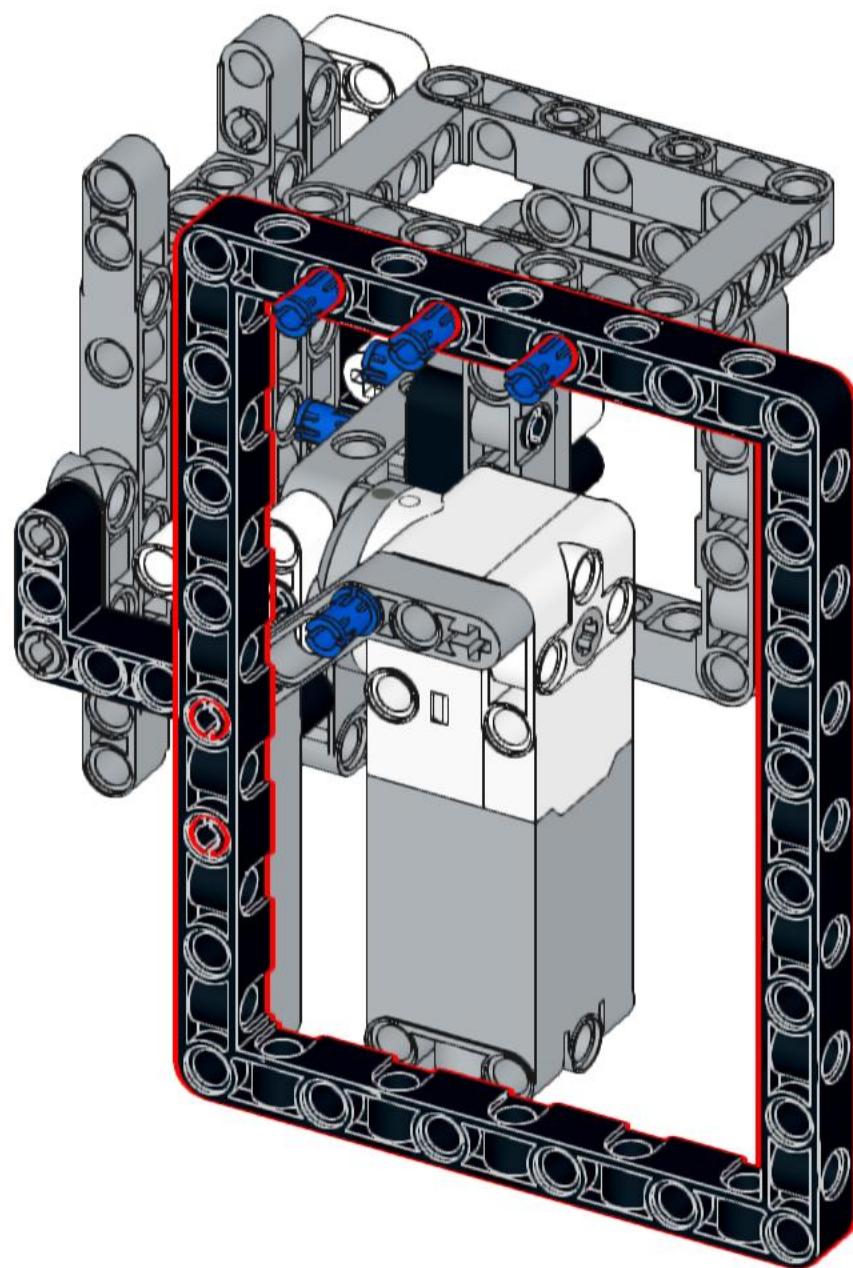
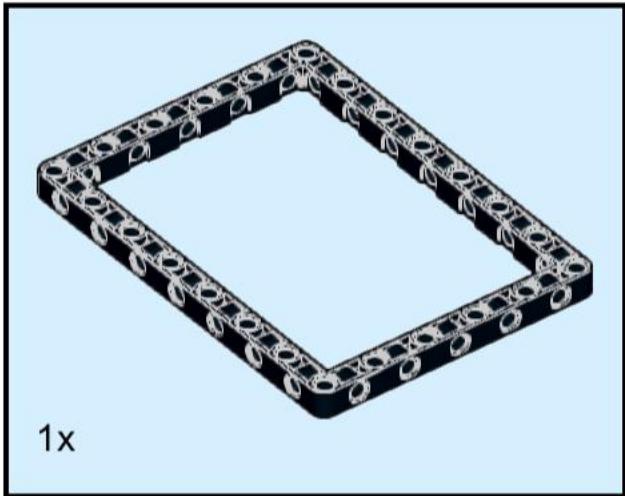
1x



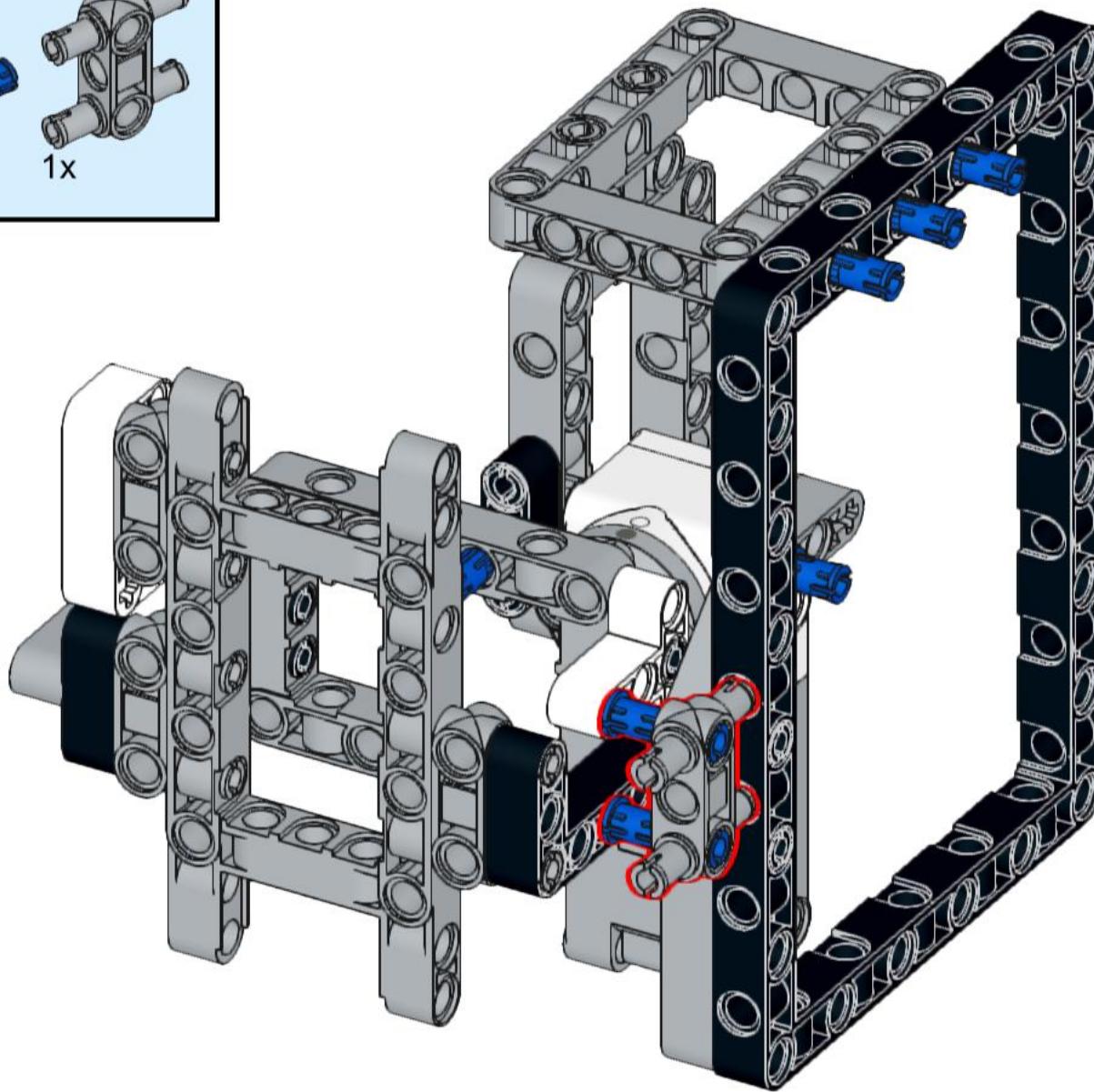
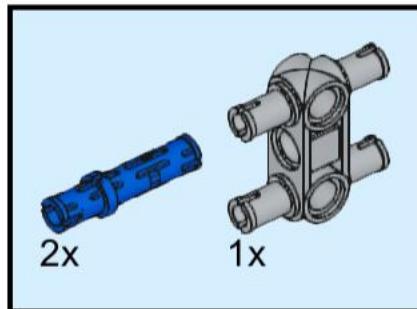
**65**



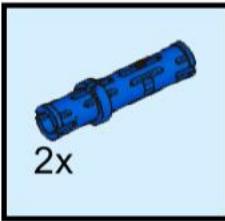
**66**



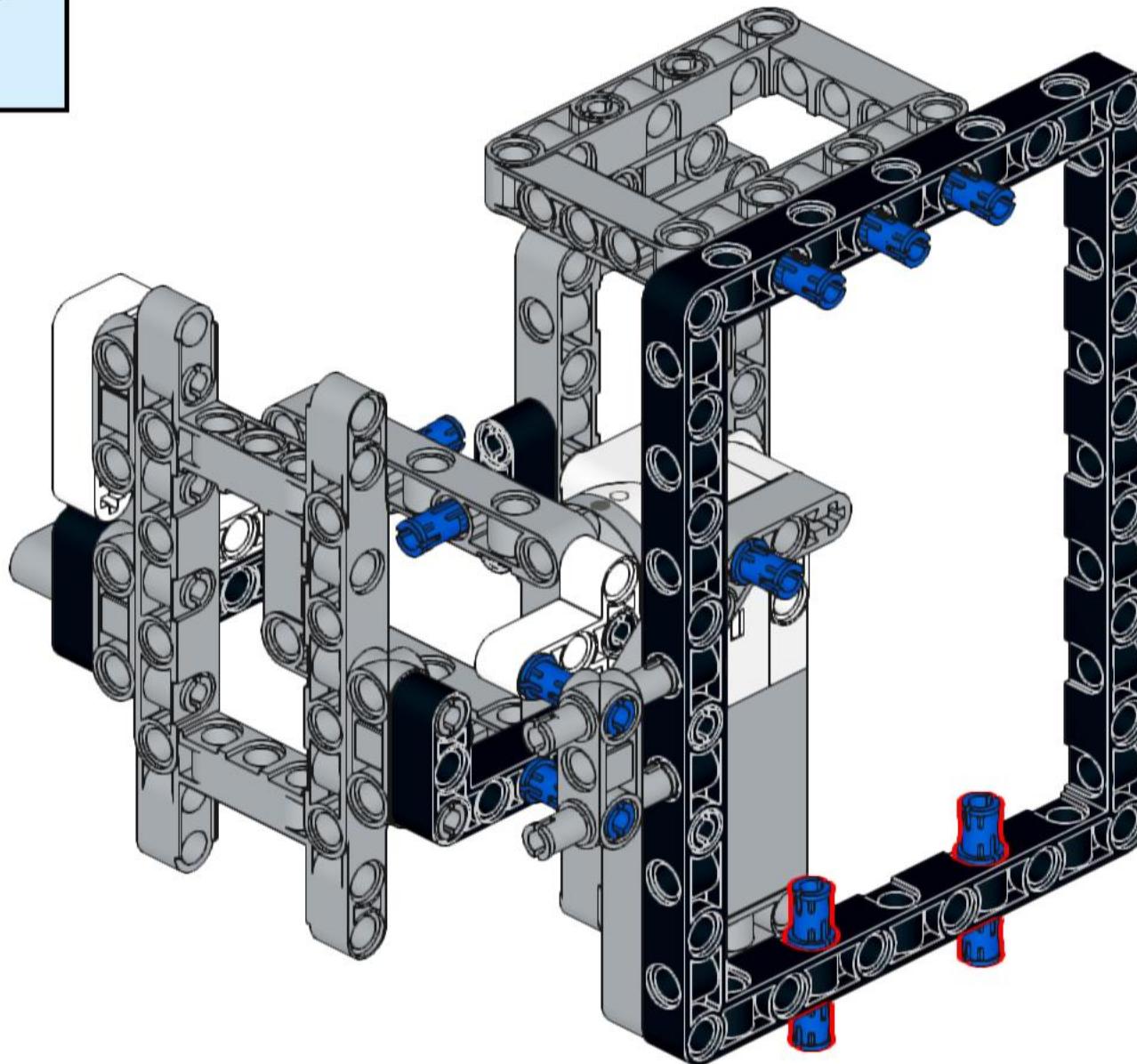
**67**



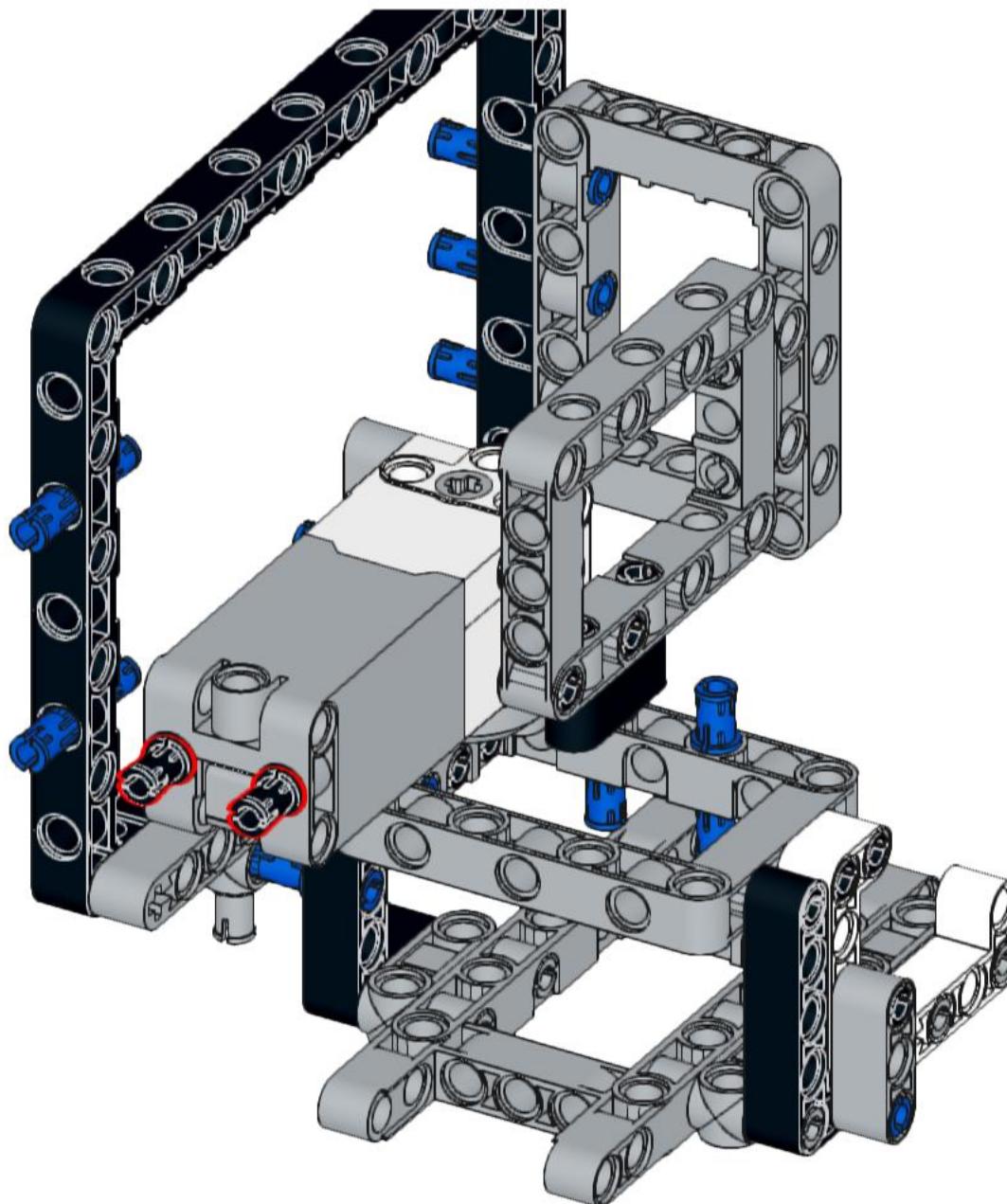
**68**



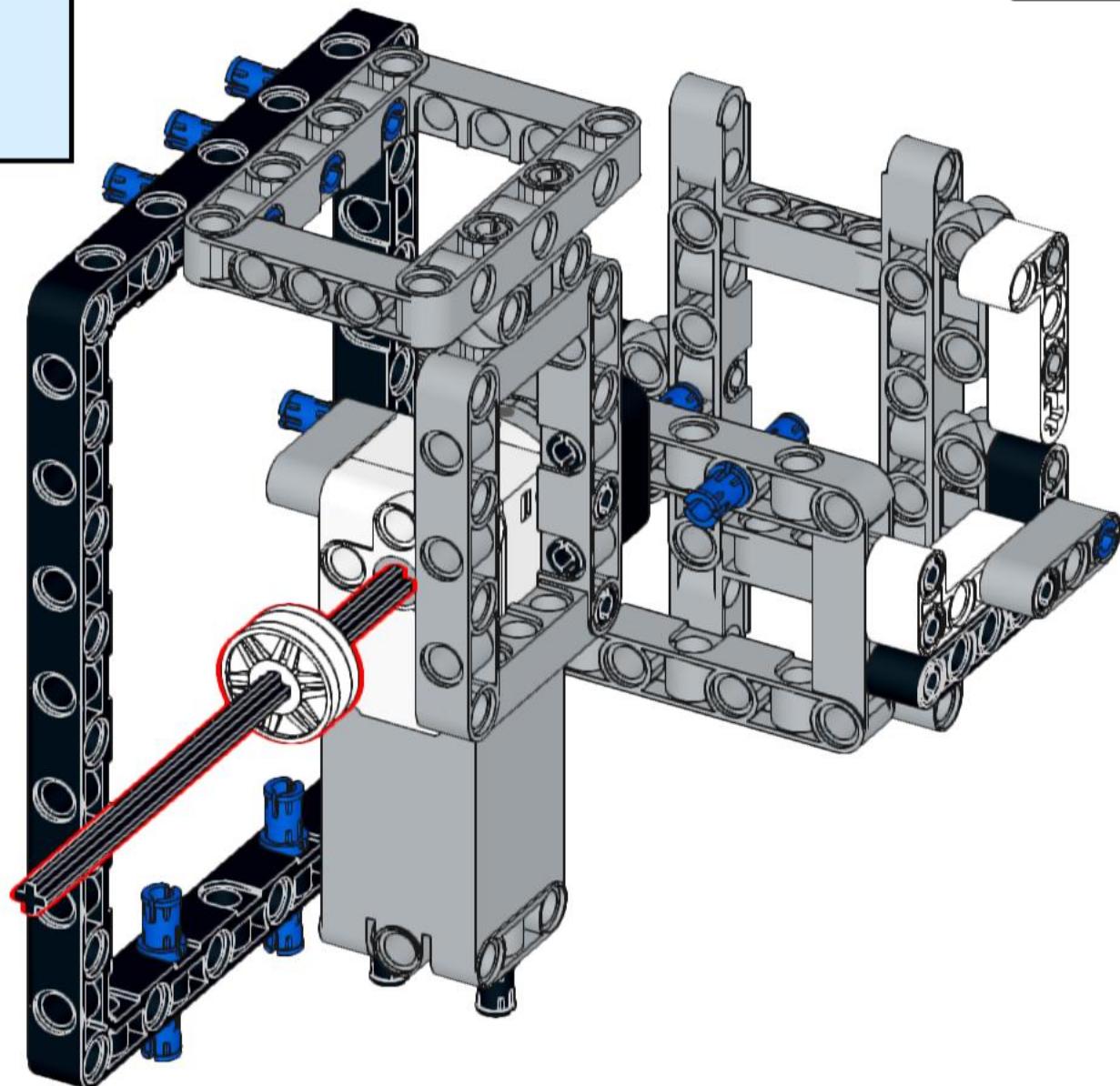
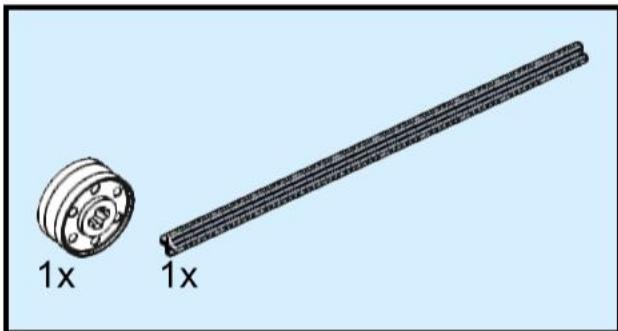
2x



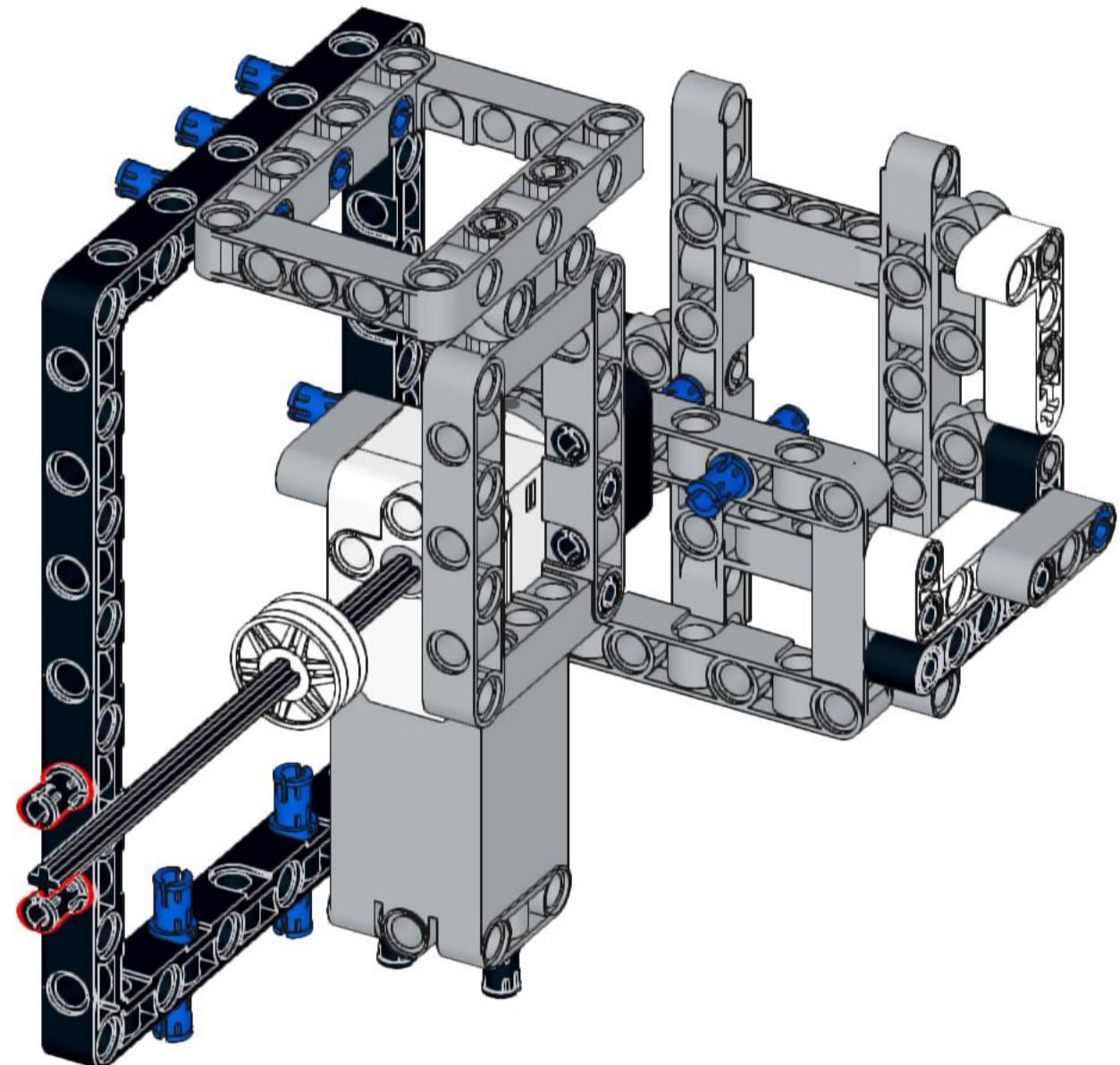
**69**



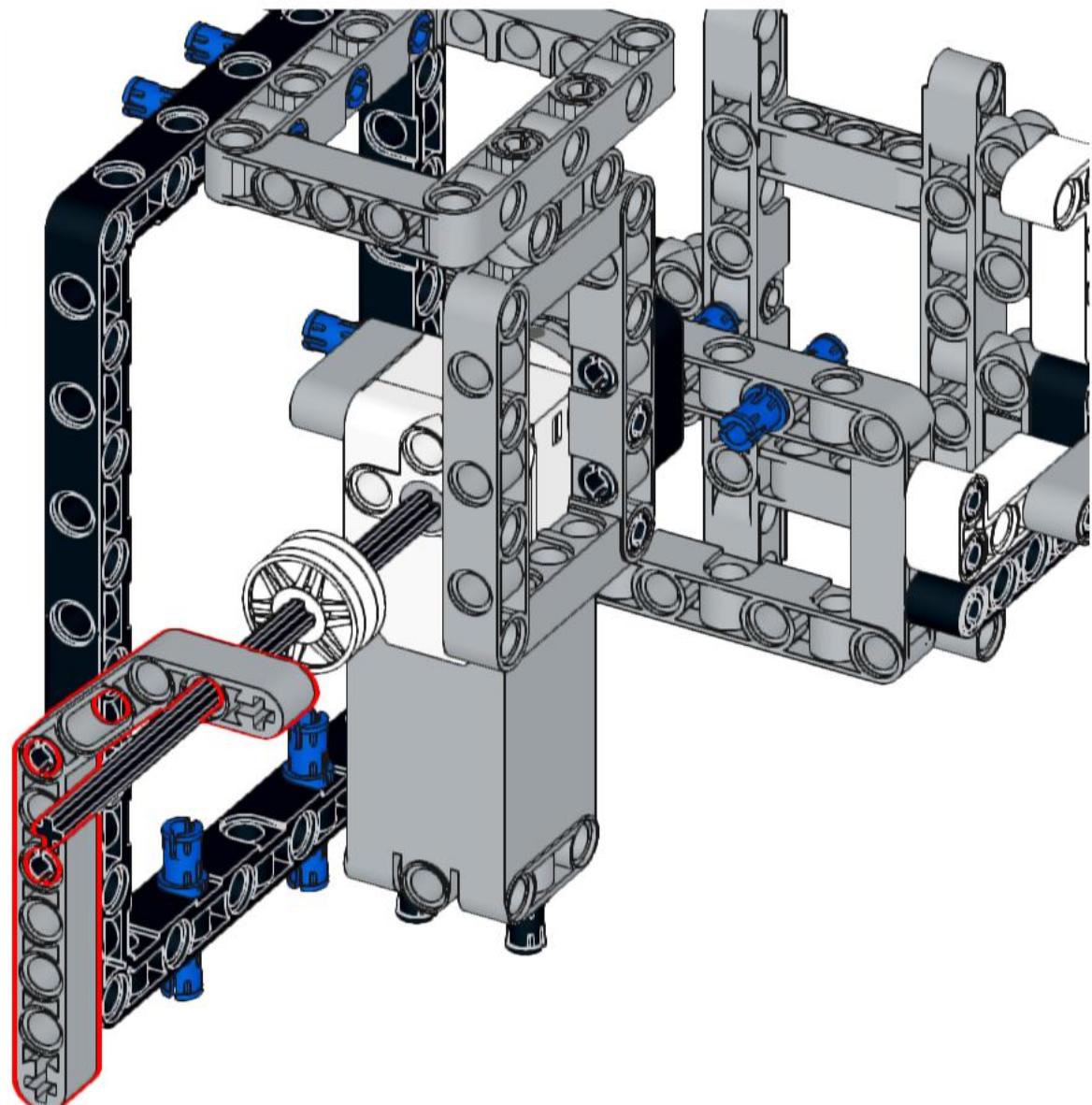
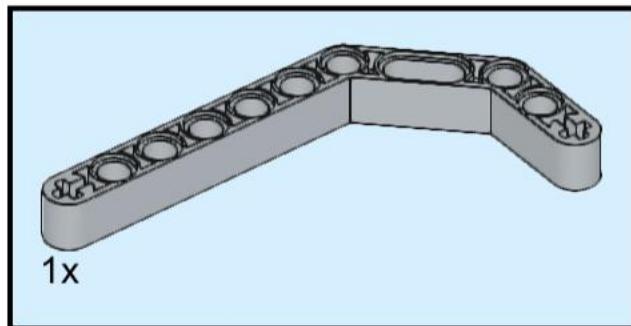
70



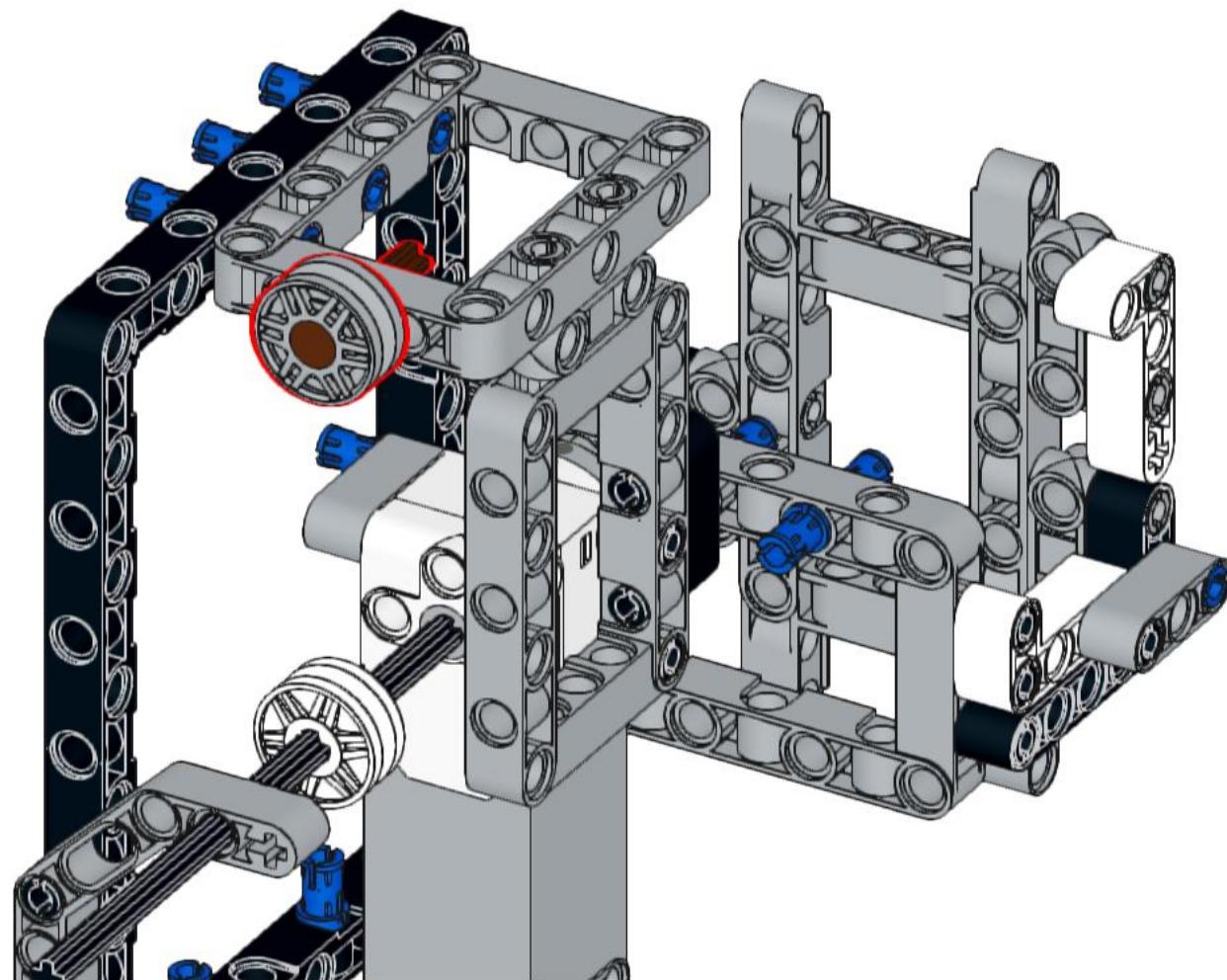
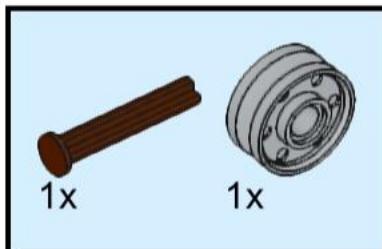
71



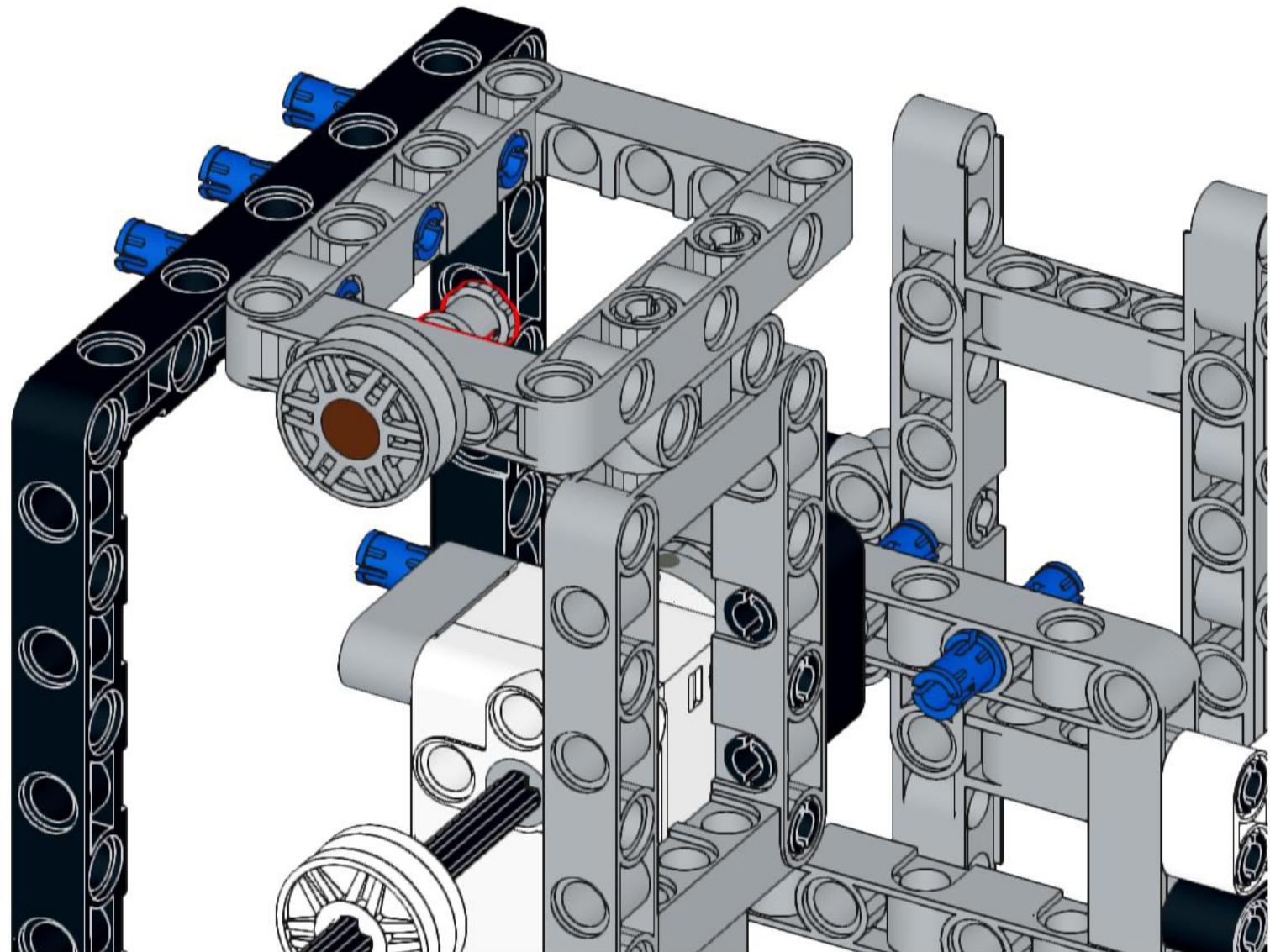
**72**



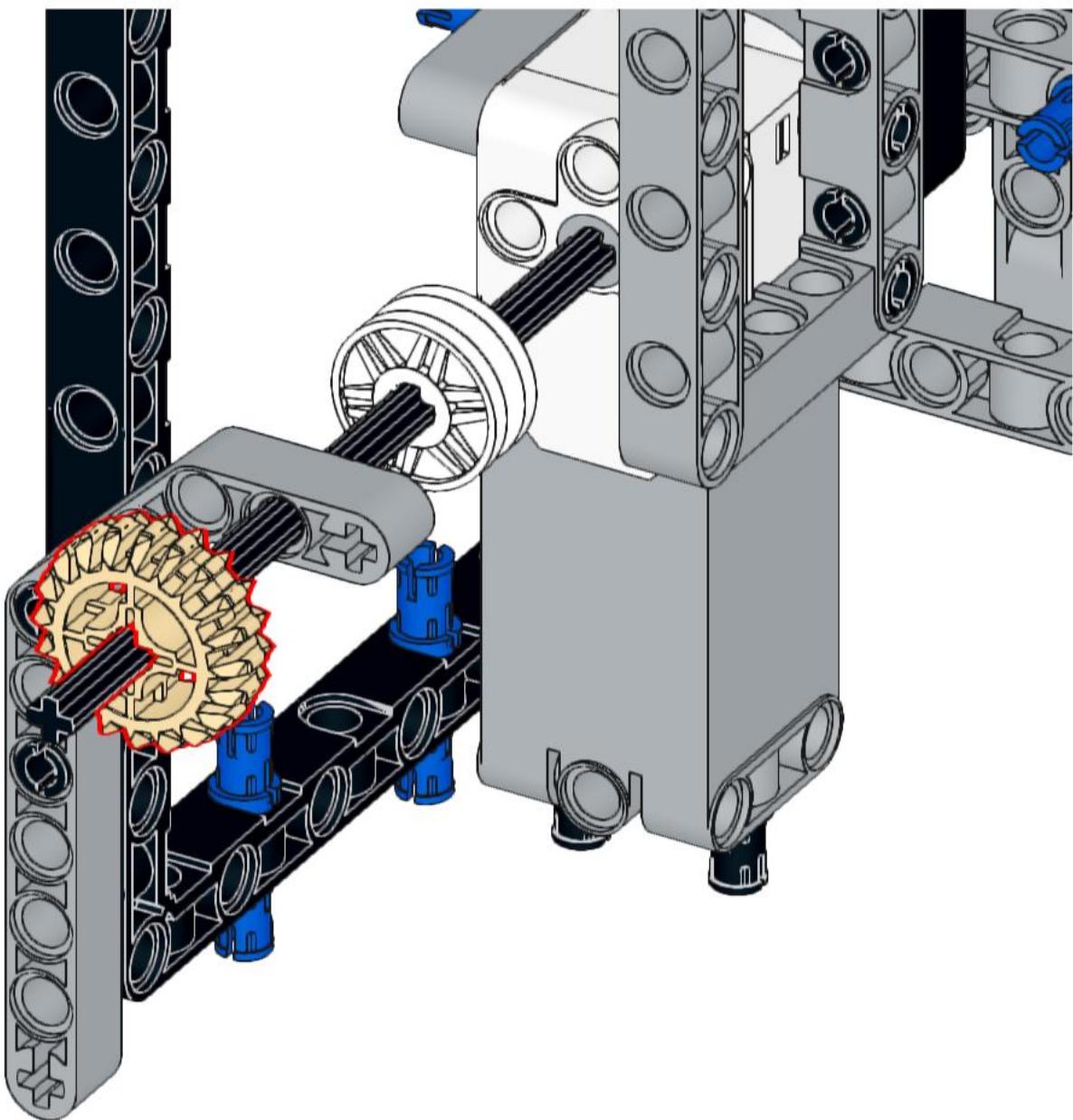
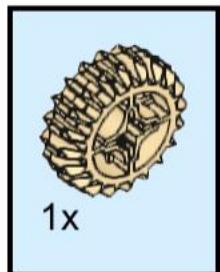
73



74

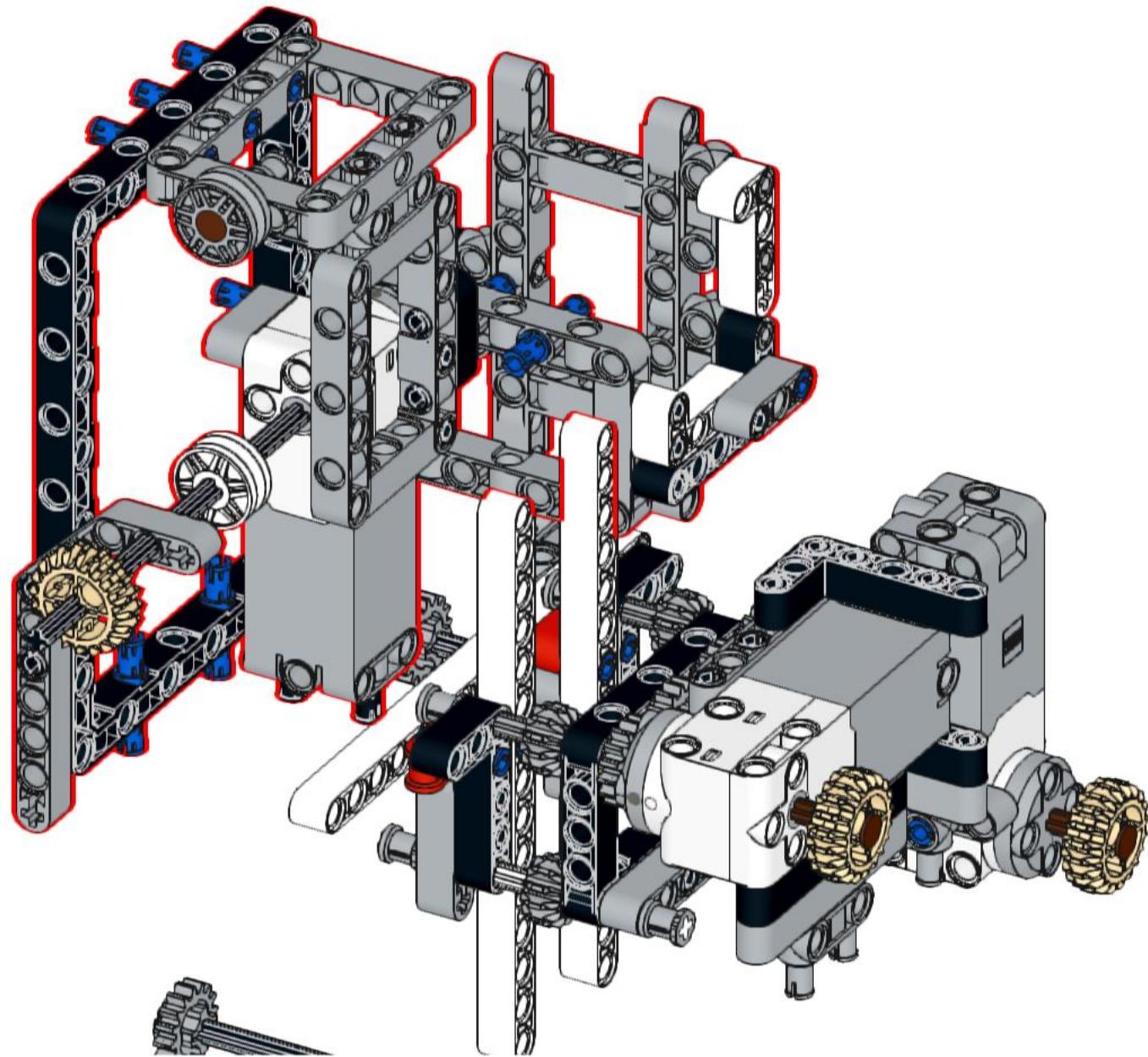


75

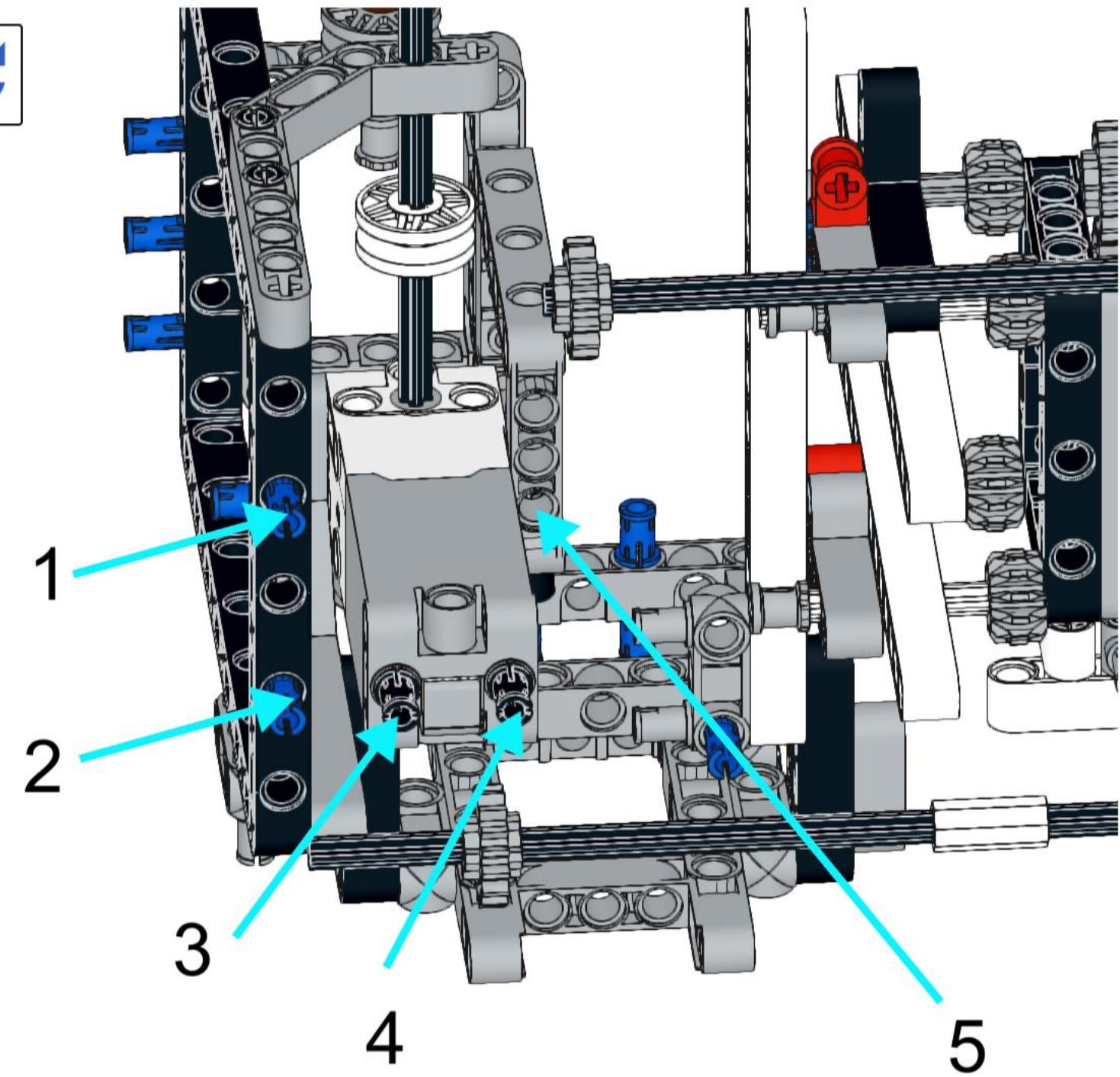


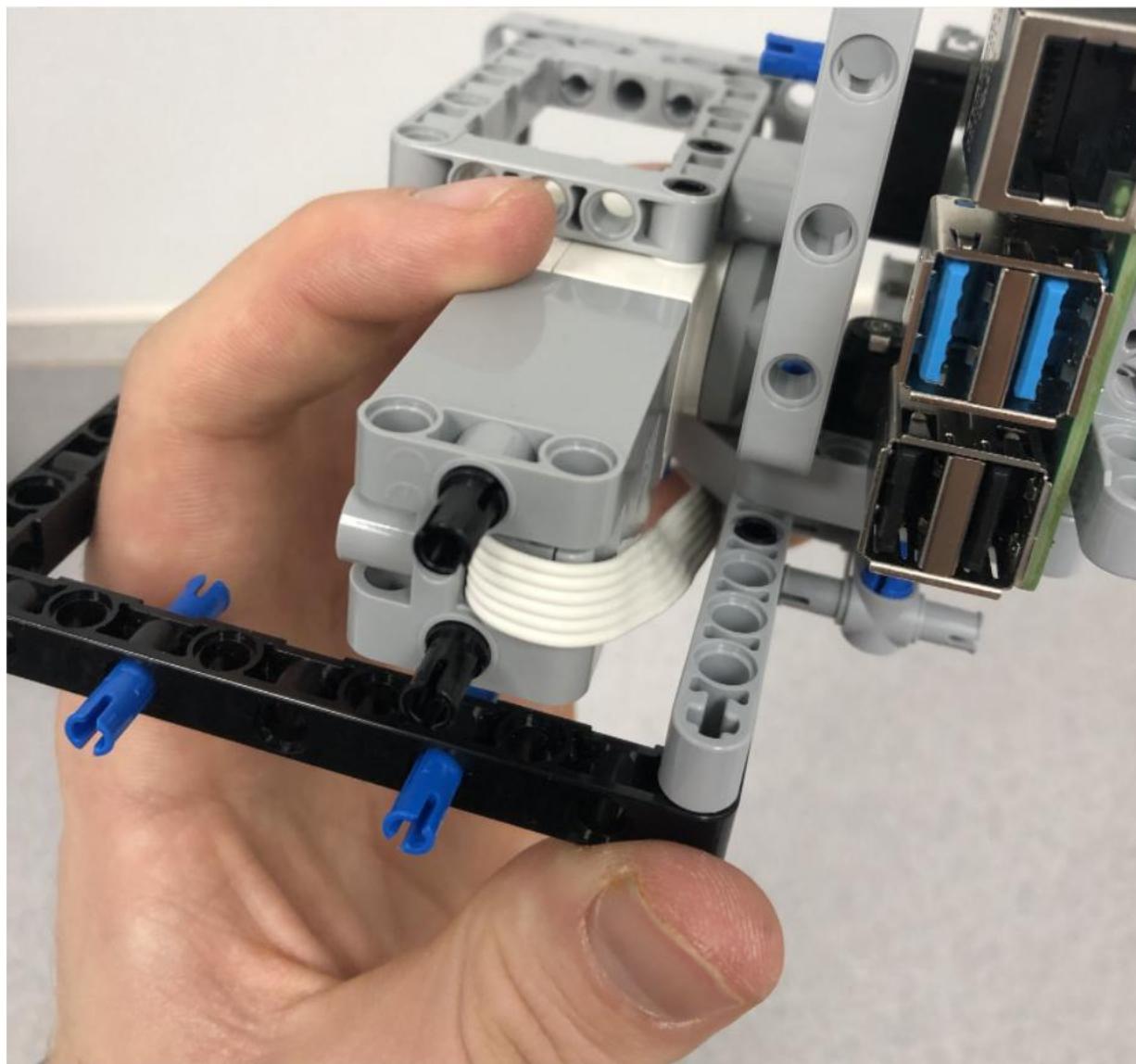
# 76

To connect to the cart base, identify the 5 main connection points and their location on the frame (see next few pages)

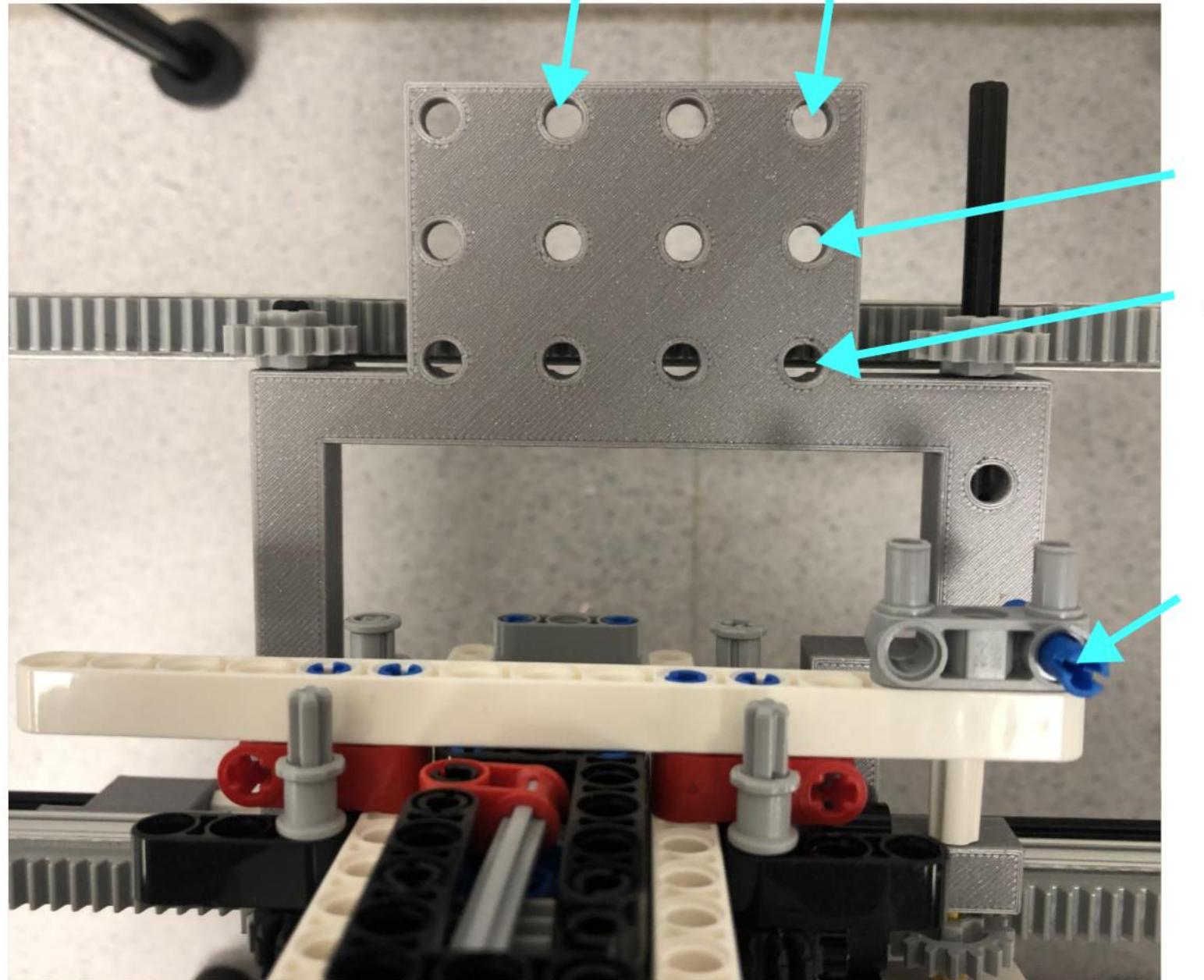


77





Prior to making any connections, ensure that the motor cable is wrapped through as shown here



1

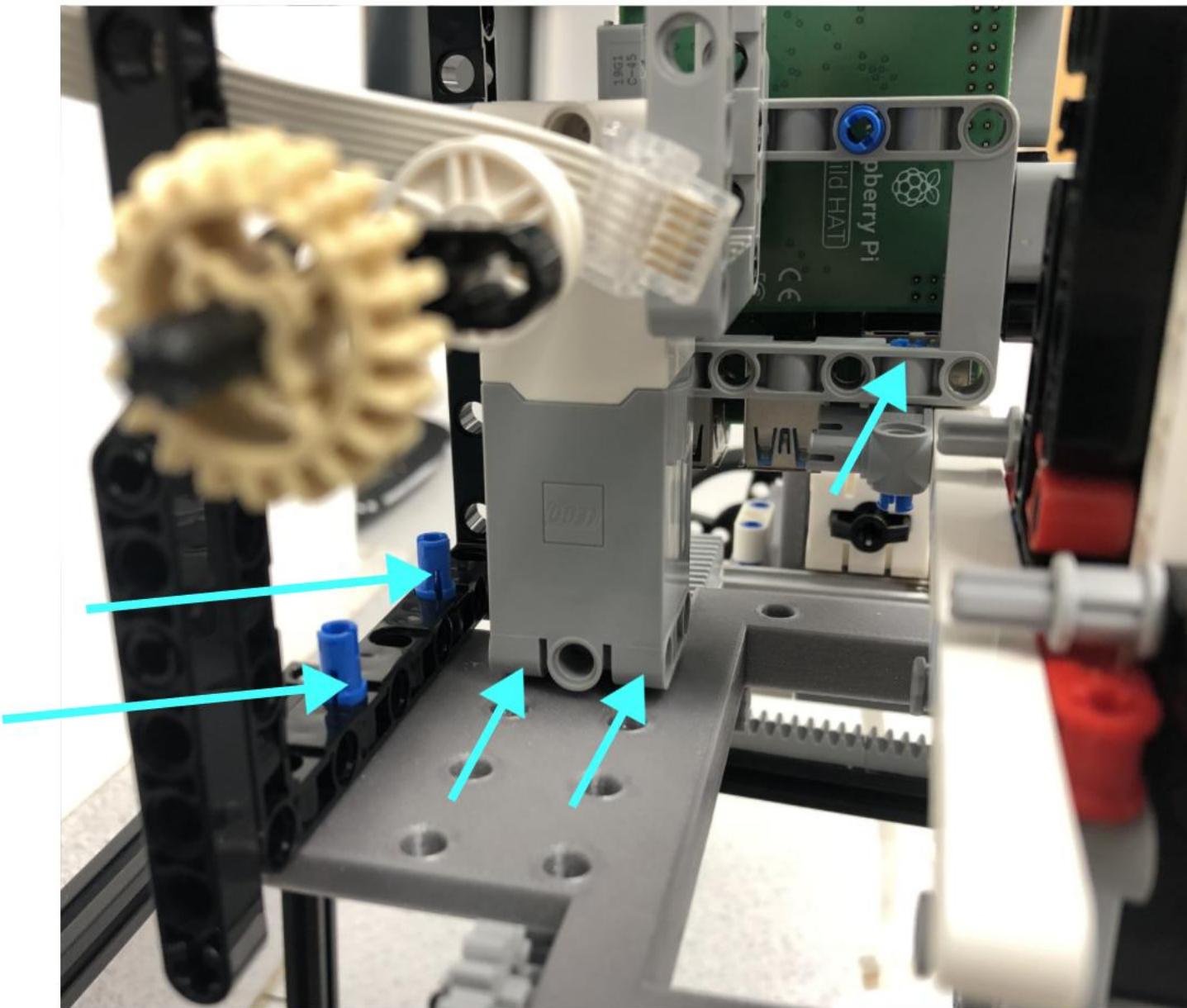
2

3

4

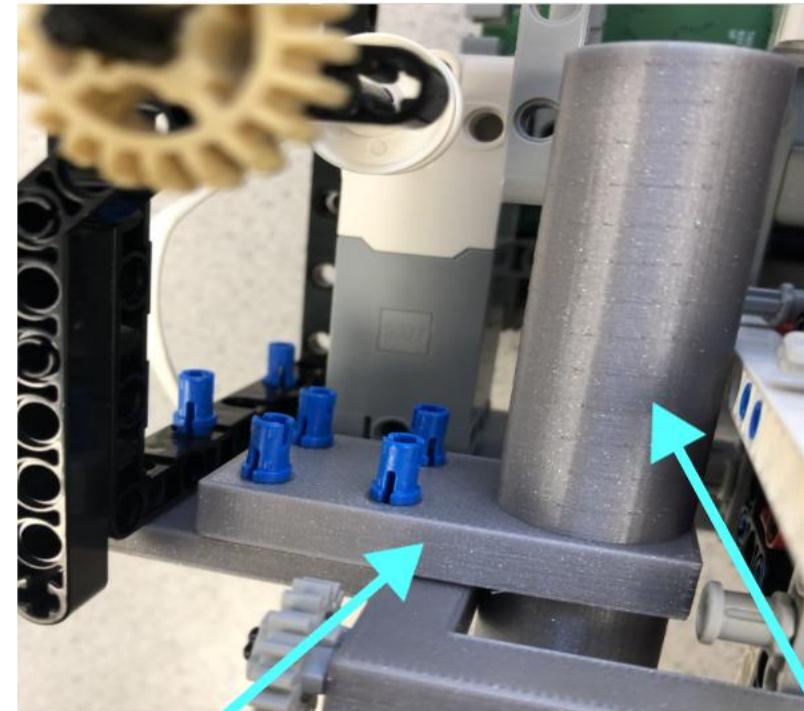
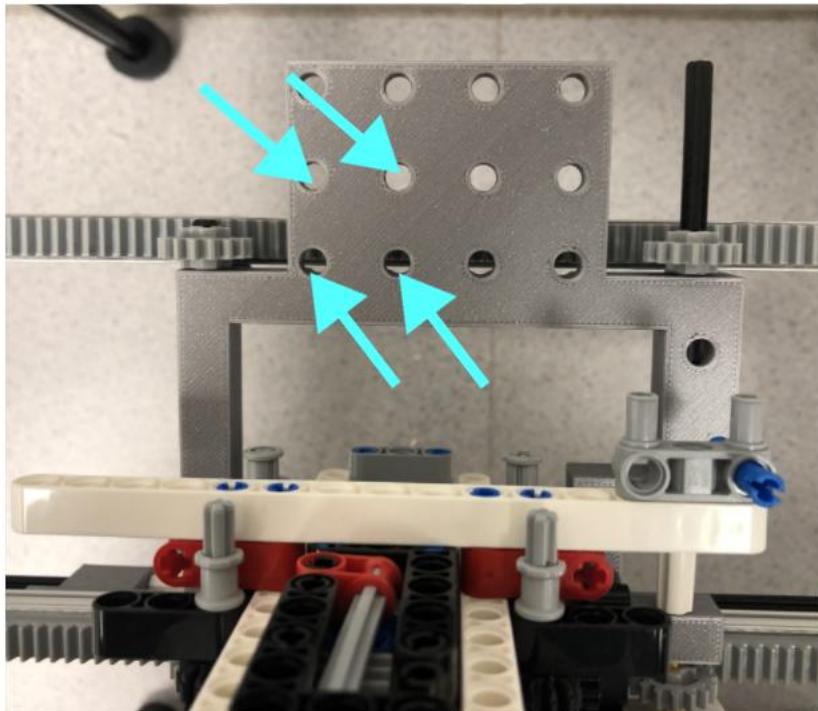
5

Here is another view of the attachment areas





Next, we will add the pH Outer Guide tube to the cart frame. If it has been printed with support material as shown here, carefully remove any of this and ensure no strands or debris are left.



Guide Tube Plate

Guide Tube Cylinder

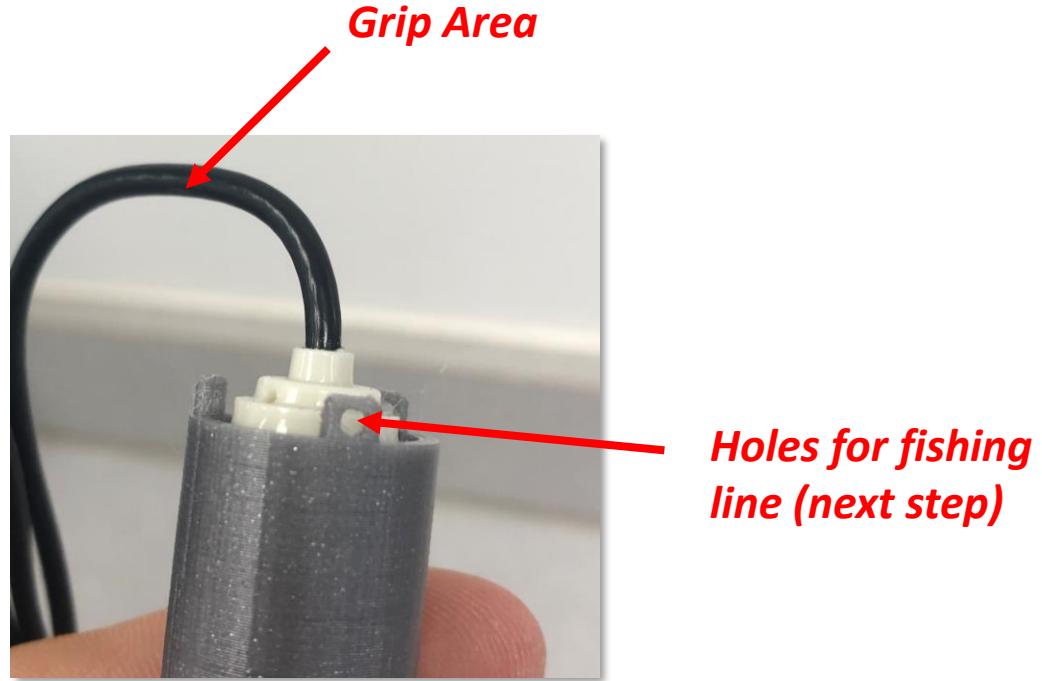
Keeping the long-end of the guide tube cylinder facing down, insert the 4 Long Blue pins through the Guide Tube plate into the Cart beneath (see left image for proper holes). This can be a tight fit, and if it becomes too difficult you ultimately only need to insert 2 blue pins to keep it in place.



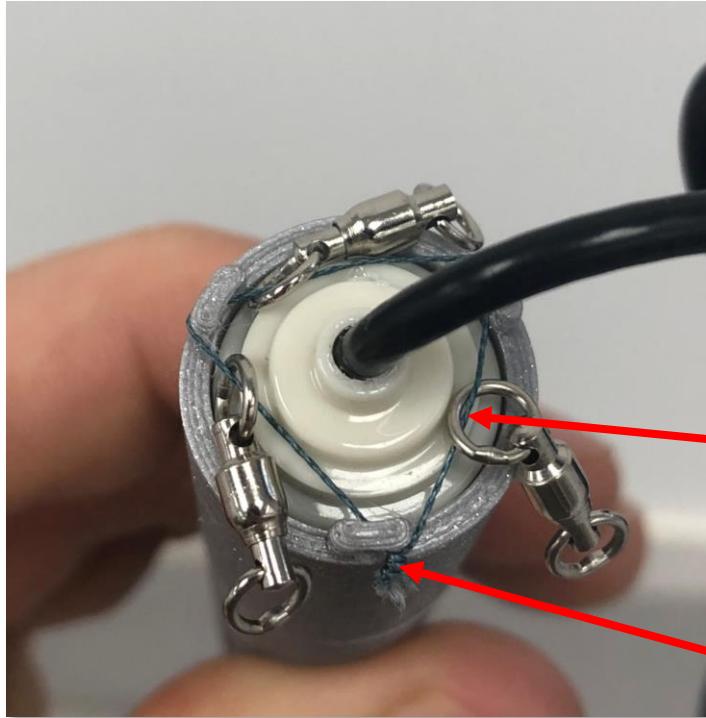
Next we will install the pH sensor (*left*) onto the trolley, first fitting the sensor properly into the 3D printed sleeve. In the method of attachment shown here, you will then need small (~12 mm length) ball bearing swivels (*middle*) and it is recommended to also use some thin polyethylene fiber braided fishing line (*right*), although any kind of string/line can work. The type of sensor desired for an experiment can be changed by adapting this process for alternate geometries/functionalities, and may require the design and printing of new 3D printed parts to attach to the Trolley Cart.



The as-received pH sensor (*left*) will come with a detachable reservoir for holding a pH storage solution. It is important that the glass bulb in the sensor not dry out or spend too much time (>30 minutes) sitting out. This solution is typically 1M KCl. To avoid the solution, first unscrew the reservoir (*middle*) and then carefully slide down the gap & gasket, taking care not to touch the end of the probe or squeezing it (it is very fragile). Screw the cap & gasket back onto the reservoir (*right*), and place aside in an area where it will not get knocked over.



Insert the bare pH sensor into the 3D printed sleeve (*left*) so that the white end is visible only at the top (right). It the sensor should not be able to move right now. *Note the area pointed out by the arrow in the right image: in later steps you will hold this portion of the wire to gain leverage for removing & replacing the cap/gasket without damaging either the sensor or 3D printed sleeve.*



**Line passes  
through one end  
of each swivel**

**Slip Knot**

Next, run the braided fishing line through each of the 3 holes, passing the line through one end of a swivel between each hole. Tie off the line with an adjustable (sliding) knot and pull relatively tight so it forms a triangle shape with little slack. Do not pull too hard, or you will rip off the thin 3D printed frame around the holes. Trim any extra line.

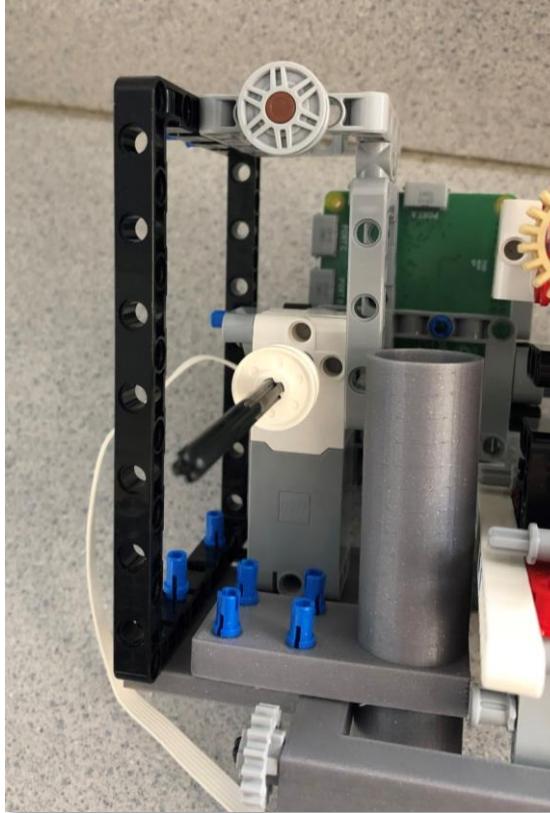
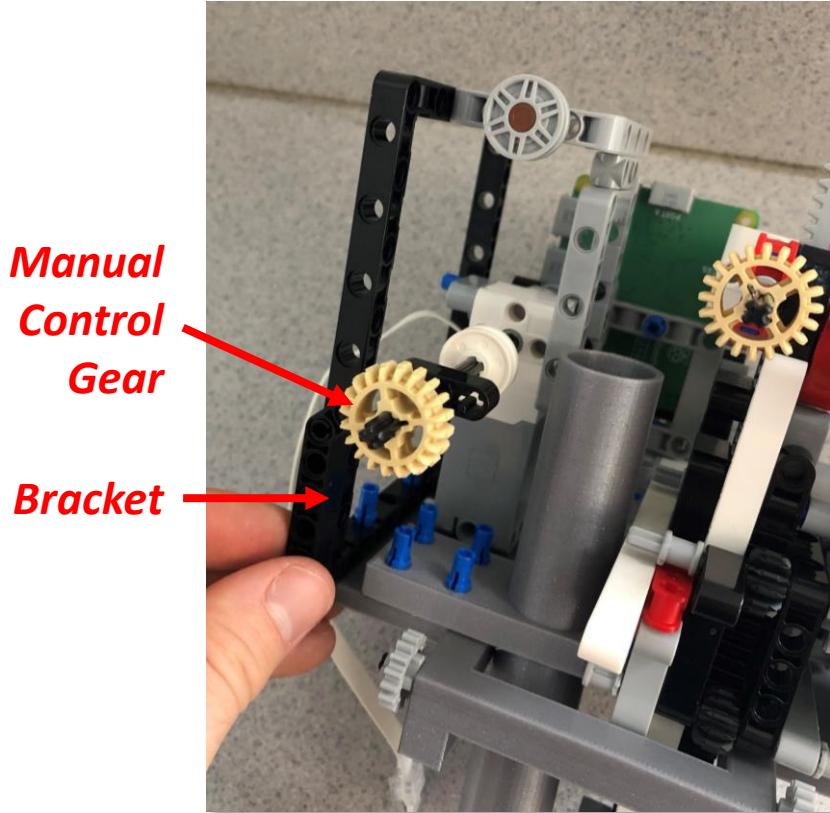
*Note: The [slip knot](#) used here is an example of an adjustable knot and may require some dexterity to produce.*

***Leave around 18" of line to work with***

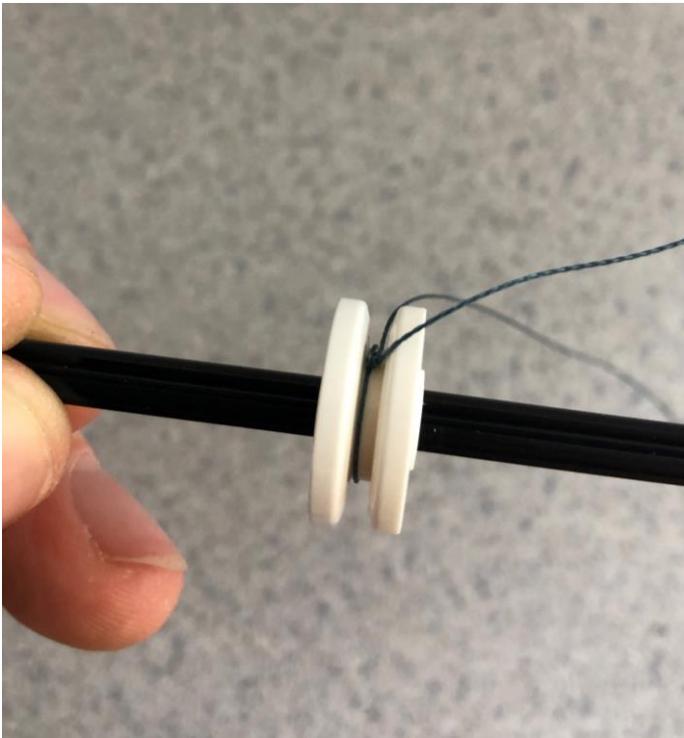


Now tie a line around the wire, running it through the other end of each swivel so that they are cinched onto the line. Again, do not pull too hard when pulling tight, or it could pull the other line up and break the frame around the holes,. This time, do not trim the line right next to the knot. Instead, leave around 18" of line to work with (this will be used to wrap around the pulley on the trolley, for lifting-up the pH sensor)

*Note: This also uses a slip knot.*

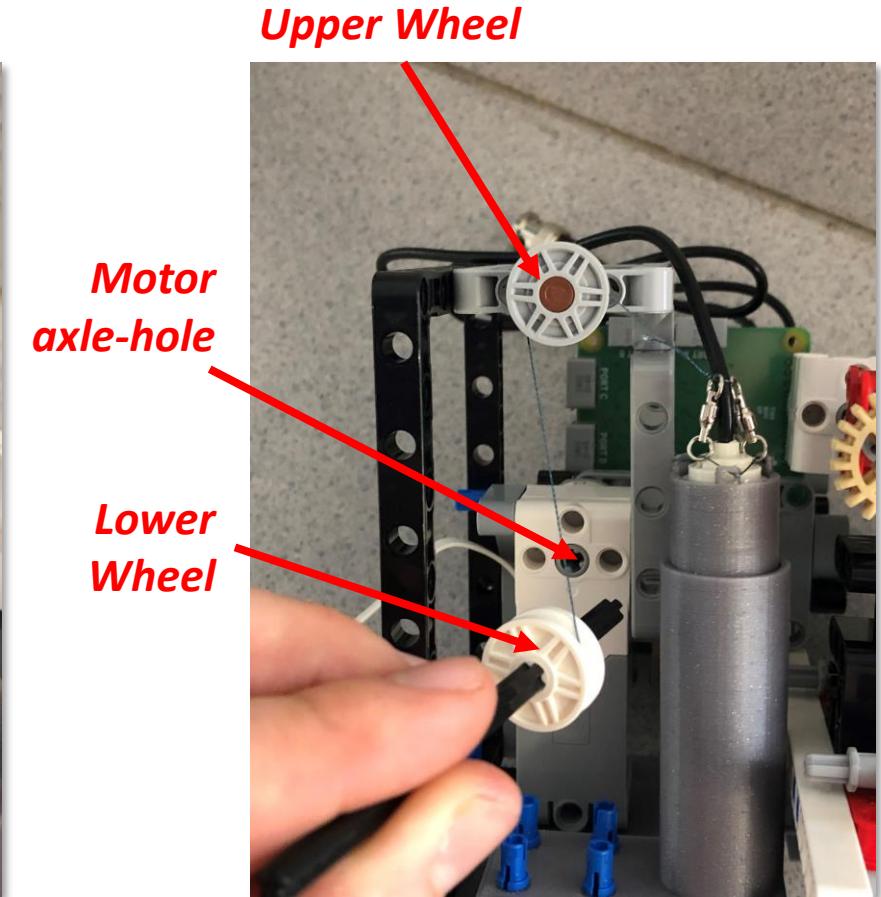
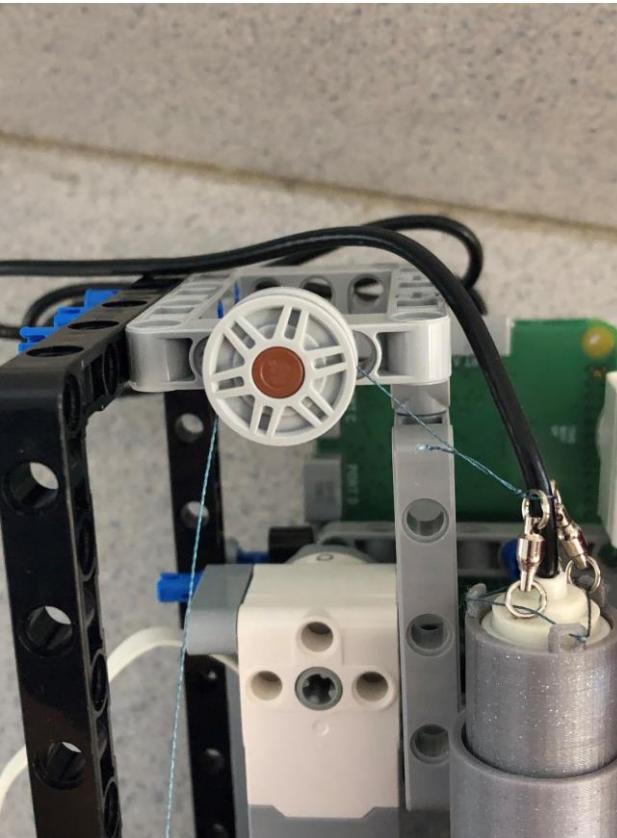


Remove the bracket and manual control gear from the trolley (*left*) so that the pulley axis is accessible (*middle*).  
Remove this axis, keeping the pulley wheel on it (*right*).

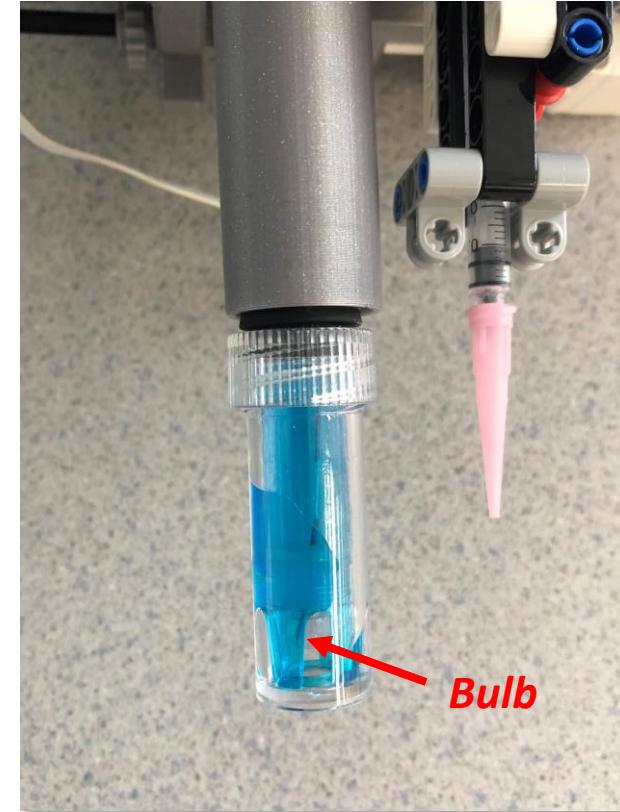
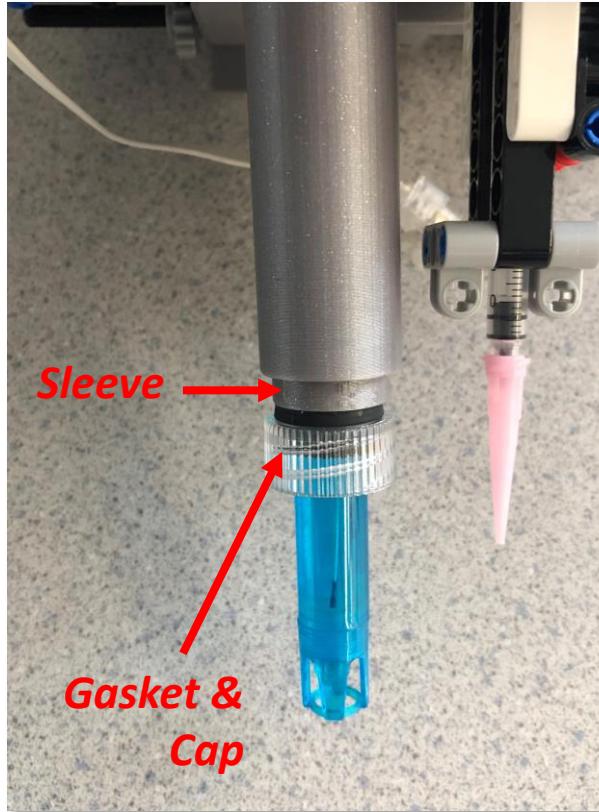
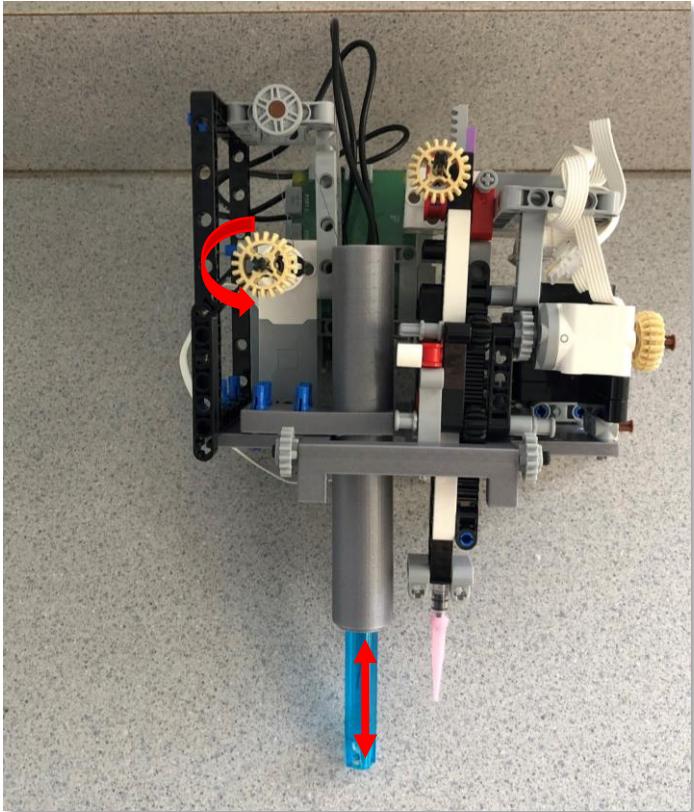


Tie the other end of the 18" or of line to the pulley wheel with a slip knot, trimming any excess line after (*left*). Pull this tight so the knot is against the interior rim of the wheel. Rotate the axle and wrap up the line so there are only about 6-8" left unwrapped (*middle*). Undo the cable tie around the pH sensors BNC wire (*right*)

*Note: This also uses a [slip knot](#).*



Insert the pH sensor & sleeve into the top of the guide tube on the trolley, making sure to keep the wire and line out of the way (*left*). Let the sensor & sleeve fall farther into the tube and pull the line around the top of the upper wheel (*middle*). Rotate the pulley axle so there are only 1-2" of line left unwrapped and align it with the motor axle-hole while keeping the line taught so it doesn't slip off the upper gear (*right*). Insert the axle into the axle-hole and slide the lower wheel (if needed) along the axis so that it rotates in the same plane as the upper wheel.



The pH sensor & sleeve should not ascend and descend (when the cart is mounted vertically) at the control of the manual control gear (*left*). Try this out to ensure it is working properly. If it is not descending, this is likely due to the BNC wire of the sensor getting caught (this will be dealt with in the wiring instructions). Lower the sensor far enough so that the 3D printed sleeve starts to appear, and holding the BNC wire in one hand, push the gasket & cap back on until they press against the sleeve (*middle*). Screw on the reservoir, ensuring that the storage solution covers the glass bulb completely (*right*).

*Note: Once reservoir, cap & gasket are on, the pH sensor will be unable to be raised. To use it for experiments or calibration, you must remove these elements again, as per the instructions elucidated earlier.*