MODEL 10

Plotter

I write and paint your idea!

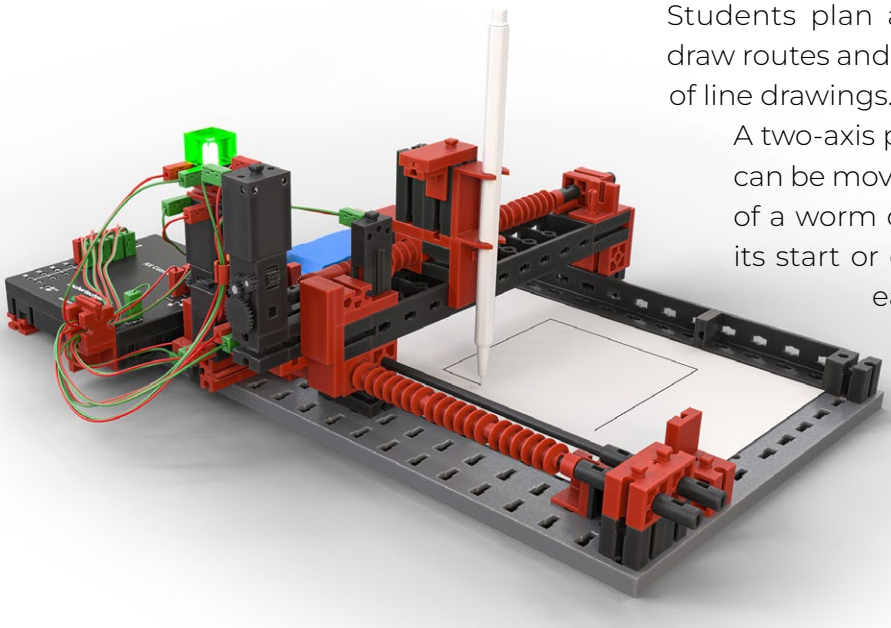
KEY QUESTIONS:

- **Where can automatic drawing or cutting be used in everyday life?** ***(Communication)***
- **What functions does the system need to fulfill?** ***(Collaboration)***
- **Under what conditions should the system switch on or off?** ***(Critical thinking)***
- **What needs to be considered to ensure that the system can be used with different media (paper, film) and that the system functions as robustly and reliably as possible?** ***(Creativity)***

THE TEACHING CONCEPT AT A GLANCE

Grade level:	5–7
Time required:	2 (up to 8) double lessons
Degree of difficulty:	Model up to Programming up to
Model type:	mobile device, can be positioned and used individually

MODEL DESCRIPTION / TASK



Students plan and implement a plotter that can draw routes and thus enable the automated creation of line drawings.

A two-axis plotter is built for this purpose, which can be moved in the x and y directions by means of a worm drive. The plotter can safely move to its start or end position using a end switch for each axis. The travel paths are measured using pulse wheels with 4 pulses per revolution so that the plotter can be positioned precisely at ¼ revolutions.

EVERYDAY RELEVANCE

The automatic triggering of a process has a strong motivational effect on students. The automatic creation of line drawings is quick and easy to understand for everyone. Two additional options to the basic task allow the topic to be individualized.

The topic could be integrated into preprofessional orientation with regard to information technology or design professions.

Automated printing or drawing (plotting) is used here in many fields. In particular, the sensor-based detection of movements is becoming increasingly important in many areas of production technology, e.g. laser cutting or 3D printing.

The two-axis plotter is therefore a very good introduction to automated 3-axis production.

SUBJECT REFERENCE

- **Information technology:** Programming basics, time loops, saving variables, comparisons, loops, travel paths
- **Physics:** Electric motor, change in motion, linear motion
- **Technology:** stable construction, construction technology, gears, conversion of rotation into linear motion
- **Mathematics:** Coordinate system, coordinate geometry, linear functions

LESSON PLAN

Introductory phase

Classroom discussion	• Announce the topic; if necessary, use “3D printer in action” or show the shutter/screen control in the classroom. • Inquire about what constitutes this control, automation vs. manual control. • Inquire about scenarios in which technical systems that move automatically in a linear motion are used (roller shutters, yard gates, 3D printers, CNC milling machines, cutting plotters ...). • Discuss possible applications of the collected scenarios. • Determine the requirements for a two-axis plotter. • Discuss the advantages and disadvantages of different types of drives (chain/wheels/worm). • Justify the need for an end switch, a path or time control, and an emergency stop switch.
Support, if necessary	• Show sensors, actuators and components from the assembly kit, use presentation media if necessary.

Planning Phase	
Classroom discussion	• The procedure for building the model and the target function are developed jointly. • Sequence steps of the app are specified or discussed.
Partner or group work	• The students familiarize themselves with the app and download the corresponding task. • Students recognize the useful functions of a plotter. • Students draw up the list of requirements for the device.
Optional: Partner or group work	• Optionally, the students sketch possible two-axis plotters. • The students discuss their results in the group and decide on a design.
Construction Phase	
Partner or individual work	• The students use the app to build the plotter. The app guides them through the program in short steps.
Programming Phase	
Partner or group work	• The students write the program for the two-axis plotter (2 motors/4 buttons). The app guides them through the program step by step. The app offers assistance. • The program is transferred in the RX controller.
Experimentation and Test Phase	
Partner or group work	• The plotter is put into operation and tested. • Pressing the On/Off button on the controller starts or ends the program. • Possible malfunctions in the functional sequence must be found and eliminated. • Suggestions in the app can help with possible troubleshooting. • Possible hardware optimizations (e.g., second linear guide, second end switch, optimization of the pen holder) and programming.
Final Phase	
Optional: Presentation and allocation of differentia-tions	• Quick students are offered the possibility of differentiation. The teacher approaches eligible students. • The additional procedure is realized via the app.
Discussion in plenary	• Project debriefing in class. • Clarification of future application possibilities in everyday life (transfer of the topic to everyday life), e.g., plotter, printer, CNC milling, automated production.

METHODOLOGICAL AND INSTRUCTIVE TIPS

Differentiation options

Depending on the duration of the lesson series and the strengths of the students, the following are possible:

- the length of the travel path per 90° rotation is specified,
- the length of the travel path per 90° turn is measured by the students,
- the route program blocks are specified,
- self-measurement of the routes,
- self-programming of the routes,
- the plotter is equipped with end switches in the other end positions,
- the students retrofitted a second linear guide on the bridge for stability reasons,
- the students can retrofit a third axis for raising and lowering the pen.

Motivational Aspects

All students are familiar with 3D printing and plotting from everyday life. The automatic detection of a status has long been part of everyday life in many smart applications. For example, students are familiar with corresponding circuits from an automatic roller shutter control system or from an automatically closing yard or garage door or elevator doors.

These linear movements in onedirection are now supplemented by a second direction in this project. All students are familiar with the planar x-y coordinate system from their math lessons.

PROGRAMMING SKILLS

- Program start
- Continuous loop
- Integration of sensors
- Integration of actuators
- Loop **if – then**
- Loop **repeat until**
- Loop **wait**
- Loop **repeat – x times** (variable-dependent)
- Integration of variables
- Change of variables
- Working with subprograms
- Subprograms with transfer variables

ADDITIONAL MATERIALS

Optional download:

- Circuit diagram
- Building instructions

- If available, a roller shutter control system, a 3D printer, a 2D Styrofoam cutter, or other real objects from the field of automated control/manufacturing can be used for the introductory phase of the topic.
- Drawing media (paper, whiteboard, or projection screen).

FUNCTIONS OF THE MODEL AND THEIR TECHNICAL SOLUTIONS

Function of the sensors/actuators	Technical solution
Executing a movement in the x-direction	Control of the x-axis motor
Executing a movement in the y-direction	Control of the y-axis motor
Stopping the movement in the x-direction	Evaluating the signals at the end switch
Stopping the movement in the y-direction	Evaluating the signals at the end switch
Control the movement in the x-direction	Evaluating the signals on the rotation counter/button
Controlling the movement in the y-direction	Evaluating the signals on the rotation counter/button
Start a drawing	Signal input on the On/Off button of the controller
End/emergency stop	Signal input on the On/Off button of the controller

MATERIAL LIST

Sensors	Function
1 On/Off button on the controller	1. Switching on the plotter 2. Emergency stop of the plotter
2 buttons	End switches on the x- and y-axis
2 buttons	Rotation counter per axis in 90° steps

Actuators	Function
2 motors	Movement
1 LED	Status display of pen holder