



# Teacher's Manual

## About this Manual

This Teacher's Manual has been made to accompany the OpenPlant Biomaker No-Code Programming for Biology course developed by the Biomaker Team at the University of Cambridge. As a supplement to our Beginner's Guide, this booklet will provide useful information for those wanting to host their own No-Code Programming for Biology courses or workshops.

The manual will run through an overview and background of the course as well as its aims and objectives. We have also provided some suggested structures, teaching sheets to accompany each lesson, and some tips and advice for running a successful workshop.

More information about Biomaker for teachers, trainers and educators is available in the educators portal of the Biomaker website at [www.biomaker.org/educators](http://www.biomaker.org/educators). Materials to accompany this manual are available on the resources page at [www.biomaker.org/resources](http://www.biomaker.org/resources).

The screenshot shows three columns in the Educators Portal:

- Teacher's Manual:** A train-the-trainer style manual providing useful information for anyone wanting to host their own no-code programming workshops or training events. Includes suggested workshop structures, checklists and teaching sheets. Status: Coming Soon.
- Free Resources:** A useful collection of resources for both learners and educators, including the No-Code Programming for Biology Beginner's Guide, Teacher's Manual, tutorials, presentations and videos. All free to use, share and adapt. Status: Resources.
- Collaborations:** Learn more about our previous educational collaborations on our Global Partners page or in the news articles below. Alternatively, get in touch to register your interest in working with the Biomaker team. Status: Global Partners.

### *Biomaker Website Educators Portal*

The lessons provided in the Beginner's Guide form the core of the No-Code programming for Biology course. They can be easily adapted, and used in combination with a range of other materials provided, to customise the course for your own needs and requirements.

The skills taught on this course can be enabling in many ways, allowing biologists to expand their skill sets and make useful tools to assist in their research. We hope that this booklet provides you with the resources necessary to host your own No-Code Programming for Biology course, and share these skills with other biologists. If you have any questions or need advice in planning your own course, you can contact the Biomaker team at [coordinator@synbio.cam.ac.uk](mailto:coordinator@synbio.cam.ac.uk).



# The Beginner's Guide

## About the Guide

Designed for those with little to no experience working with coding or hardware, the No-Code Programming for Biology Beginner's Guide makes use of free open-source software and low-cost hardware to introduce participants to the principles behind making their own instruments.

The guide teaches participants how to use the free open-source, no-code programming software XOD, as well as how to use some simple low-cost hardware devices, such as LEDs, sensors and screens.

It is built to accompany the Grove All-In-One Beginner Kit for Arduino development board, designed by Seeed Studio. Alternative versions of the Arduino Uno board and accompanying components can also be used, but additional set-up and wiring may be required.



*The No-Code Programming for Biology Beginner's Guide*

The guide takes the form of five lessons, starting with basic background information and underpinning knowledge, running through several hands-on tasks of increasing complexity, and finishing with advice on how to use and expand on these new-found skills.

Throughout the course, participants will learn to:

- Understand and control an Arduino board
- Programme without using code
- Use simple electronic devices such as screens and sensors
- Build their own devices for use in biological research

You can download a copy of the Beginner's Guide from the Biomaker website at [www.biomaker.org](http://www.biomaker.org).



## Aims

By creating the No-Code Programming for Biology course, the Biomaker team hopes to:

- Provide biologists with the knowledge required to build useful research tools that are customisable, low-cost and easily accessible
- Help biologists learn new skills to aid them in their future careers
- Make biological research more accessible by reducing the cost of custom instrumentation
- Increase interdisciplinary research at the intersection of biology, engineering and computing

## Objectives

By the end of the course participants should be able to:

- Name and understand the function of the different parts of the Grove Beginner Kit for Arduino
- Identify a range of useful 'nodes' commonly used in XOD programming
- Use XOD software to create functional programmes and control an Arduino board
- Programme and use each of the onboard devices included in the Grove Beginner Kit, including simple output devices, sensors, and screens
- Use a combination of basic skills to create complex programmes in XOD, such as logic sequences and loops
- Recall examples of how these skills can be used in a biological context
- Outline how they would use and expand their skill set in order to create devices useful for their own research

A comprehensive list of objectives for individual lessons can be found in the lesson teaching sheets later in this manual.



# Course Overview

## Lesson 1

In the first lesson covers some of the basic background information participants need to know before starting to programme. First, we take a look at the guide and how to use it. Then we look at the Grove board and explore each of it's built-in devices, including how they might be used. Next, we briefly discuss microcontrollers and how to programme them, and finally we introduce participants to the XOD IDE software and some of it's terminology.

These basics help participants become familiar with the tools they will be using throughout the guide. Many of the concepts will be covered again as the knowledge is applied to perform hands-on tasks later in the guide.

## Lesson 2

The second lesson is all about how to get started with no-code programming and using the Arduino board. Beginning with 'Setting up your Board', participants learn how to set up their computer, including how to download the XOD IDE, USB drivers and Biomaker tutorial files.

This is followed by two tasks: 'Testing your Board' and 'Input and Output Devices'. In Task 1 participants use the XOD IDE to test their connection and programme the simple LED on the board. In Task 2 participants learn how to build a simple device using the button and buzzer modules on the board, as well as expanding their knowledge of how to use XOD.

## Lesson 3

This lesson explores some of the most useful nodes XOD has to offer. These nodes are commonly used when building simple instruments, and will give participants a good base to start from when exploring more complex devices.

This lesson is split into three tasks. Following on from Task 2 in lesson 2, Task 3 explores 'Tweak and Watch Nodes', which are useful for simulating and troubleshooting. Task 4 examines 'Flip, Clock and Count Nodes' which are useful for ensuring correct timing of programmes. Task 5 looks at 'Concat, Join and Format-Number Nodes' which are useful for using and formatting text in XOD.



## Lesson 4

The fourth lesson builds on what participants have learned already, and explores some more complex concepts in XOD. This allows participants to build larger, more complex programmes and devices in a neat and efficient way.

The first two tasks in this lesson, Task 6 and Task 7 cover how to make new nodes and how to use buses respectively. These skills are useful for creating tidy, and compartmentalised programmes. Task 8 and Task 9 then explore how these skills can be used to build logic-based programmes, and how to introduce sequences and loops, which are useful for biological devices.

## Lesson 5

The fifth lesson provides information about how participants can build on their new-found skills to start developing their own custom devices.

It covers where to find components, as well as information and help to guide participants in their next steps. It also provides some examples of how previous Biomaker participants have applied these skills to real-world applications to assist with biological research in the lab and field. Finally, it provides some additional useful information including an overview of alternative development boards, a list of useful websites, a Grove board cheat sheet, a list of XOD nodes used, and a glossary of terms.

## Additional Resources

In addition to the Beginner's Guide, the following resources are available to accompany the No-Code Programming for Biology Course:

- **XOD TUTORIAL**  
The XOD tutorial is a file in '.xodball' format that runs through the tasks in guide from within XOD. It can be helpful for participants using the digital version of the guide. We suggest using this in combination with the guide, which contains extra material, especially in lessons 1 and 5. You can download the tutorial file from the Biomaker website at [www.biomaker.org](http://www.biomaker.org).
- **YOUTUBE**  
The Biomaker YouTube channel has a number of useful videos, including an introduction to the course and recordings of previous workshops. You can find the YouTube channel at [www.youtube.com/channel/UCQhsqtMhPYAxhS5Us50yT9g](https://www.youtube.com/channel/UCQhsqtMhPYAxhS5Us50yT9g).



# How to Run Your Course

## Things to Consider

How you run your course will depend on several factors. In this manual we provide a quick start guide and several suggested structures. You can also see how the course has been run previously in the recorded sessions on the [Biomaker YouTube channel](#). Ultimately, how you run your course will depend upon the requirements of your organisation and your audience. Below we have listed some things you might want to consider when planning your course.

<b>AUDIENCE</b>	Who are your students? Do they have any previous experience with coding/no-coding or using hardware? Why would they be interested in the course, and what do they want to learn? You may want to tailor which parts of the course you teach or include extra subject-specific materials depending on your audience.
<b>FORMAT</b>	Will your session be online or in person? This is likely to depend on (a) your audience, i.e. are they all located in one place or are they geographically dispersed, and (b) space constraints i.e. do you have an appropriate space to host your workshop in person.
<b>TIME</b>	How much time do you have for your workshop? How long should each session be, and how many sessions will you run? This is likely to depend on how much time you and your students have, and how much of the course you would like to cover.
<b>SIZE</b>	How many participants will there be? This will depend on the size of your audience and the space you have available. Even online events should be limited in size, as too many participants will be unmanageable in a practical workshop.
<b>COST</b>	Do you have a budget for your workshop, and if so how much? Costs involved might include purchase of kits for instructors and/or students, venue hire, paid online platforms, trainer/assistant wages.
<b>LANGUAGE</b>	This will depend on your audience. We currently provide the Beginner's Guide and Teaching Manual in English, and are working on a Spanish translation (contact us for further details). If your audience speaks another language to may have to translate the materials.



## Quick-Start Guide

- 1 IDENTIFY YOUR AUDIENCE**  
Key questions to ask include: What is their experience level? What are their interests? How big is my audience? Where are they based? What language(s) do they speak?
- 2 DECIDE ON A FORMAT AND STRUCTURE**  
Online or in-person? This will depend on your audience and resources. Use our suggested **Course Structures** for inspiration.
- 3 MAKE A SCHEDULE**  
Set a date(s) to run your course, then add in dates for key milestones. The **Pre-Workshop Preparation** section of this guide contains some examples.
- 4 ADVERTISE YOUR COURSE**  
You can advertise within your organisation and/or online via posters, email, websites, newsletters and social media. You can find some template designs for advertising your course in the **Appendices** and on the Biomaker **Resources Page**.
- 5 REGISTER PARTICIPANTS**  
Provide a way for participants to register, such as a website form, event hosting site or by email. Make sure to keep a list of names and contact details. Be aware of data protection laws when you collect information.
- 6 DISSEMINATE INFORMATION**  
Provide participants with information about the course beforehand. Confirm logistics (time, place etc.), provide a rough schedule and ask them to complete any necessary pre-workshop tasks. The **Appendices** and Biomaker **Resources Page** have some useful resources for this.
- 7 PREPARE EQUIPMENT**  
Make sure your participants will have the equipment they need, i.e. the Grove board and a computer with a USB port and XOD/drivers installed. You may provide this or participants may have to source equipment themselves.
- 8 RUN YOUR WORKSHOP(S)**  
Now you can run your workshop! Use the **Teaching Sheets** provided for each chapter to help you. If the workshop is online you may want to record the session.
- 9 FOLLOW UP**  
It is often useful to follow up with participants after the session to provide them with additional information and links. You may also want to share a recording of the session or get feedback. A sample feedback questionnaire is provided in the **Appendices** and on the **Resources Page**.



# Course Structures

## Comparison of Course Structures

In this section we provide four suggested structure for running the No-Code Programming for Biology course. Which, if any, of these you use will depend on your requirements and is completely up to you. Below is a comparison of the key features of each suggested structure. Each structure is explored in more detail in the following pages, including a suggested schedule for pre-workshop preparation, agendas for each session, and suggested homework tasks.

These structures are a guide, and can of course be modified for your requirements. For example, the three online sessions could be held all in one day for an intensive course, or on successive days or weeks for a slower-paced learning experience. In some cases we have provided suggested 'homework'. This is not a requirement, as the content of this work is covered briefly in each workshop, but it allows participants the chance to run through tasks themselves that may only be covered by a presentation in the workshops.

One of the advantages of running a structured course over independent learning is the opportunity for participants to discuss their learnings and how they might apply to their own research. For this reason, each of the suggested structures ends with a short discussion section, which we encourage you to include.

An example of **Suggested Structure 1: Two Online Sessions** is available as two recordings on the **Biomaker YouTube channel**.

SUGGESTED STRUCTURE	FORMAT	TIME REQUIREMENT	IDEAL NO. PARTICIPANTS	COST	MATERIAL COVERED
1	Online	2 x 1.5hr sessions	<100	£	Lessons 1-3 and part of Lesson 4
2	Online	3 x 1.5hr sessions	<100	£	All Lessons
3	In-Person	1 day (7.5hr)	20-30	£££	All Lessons
4	In-Person	2 half days (2 x 3hr)	20-30	££	All Lessons





# Suggested Structure 1: Two Online Sessions

## Details

- Format: Online
- Time required: 3 x 1.5hr sessions
- Number of participants: <100
- Cost: £
- Material covered: Lessons 1-3 and part of Lesson 4

### PRE-WORKSHOP PREPARATION

- Advertise your course and get participants to register (**1 MONTH BEFORE**).
- Make sure participants have access to kits by posting kits or advising where to source them (**2-3 WEEKS BEFORE**).
- Set up your online meetings on Zoom, Teams or any other platform and give participants joining details (**1 WEEK BEFORE**).
- Ask participants to prepare by downloading the XOD software, beginner's guide and USB drivers (**1 WEEK BEFORE**).
- Ask them to contact you if they have set-up issues. This will save significant time on the day (**1 WEEK BEFORE**).

### HOMEWORK

Ask participants to complete Lesson 3 of the guide at home between sessions. This material is covered by a presentation at the start of session 2, but it is best if participants have a go themselves. If you are sure that all participants have completed this homework you can remove the session on Lesson 3 in the second session, and spend more time on Lesson 4 and discussion.

## Session 1

- 17:00 WELCOME (5MIN)**  
Introduction to the course, the session and the instructors.
- 17:05 LESSON 1 (25MIN)**  
Content from Lesson 1 of the guide in presentation format.
- 17:30 LESSON 2**  
Content from Lesson 2 of the guide via a hands-on session. Live instructor run through (**20MIN**) followed by participants moving to breakout rooms and trying Tasks 1 and 2 (**35MIN**).
- 18:25 ROUND-UP (5MIN)**  
Information about next session and any 'homework'.

## Session 2

- 17:00 WELCOME AND RECAP (5MIN)**  
Recap some key information from last session.
- 17:05 LESSON 3 (20MIN)**  
Content from Lesson 3 of the guide in presentation format.
- 17:25 LESSON 4**  
Content from Lesson 4, Task 6 of the guide via a hands-on session. Live instructor run through (**20MIN**) followed by participants moving to breakout rooms and trying Task 6 (**30MIN**). Finish with discussion on what devices they might like to build (**10MIN**).
- 18:25 ROUND-UP (5MIN)**  
Thank attendees and tell them where to find more information and help.



# Suggested Structure 2: Three Online Sessions

## Details

- Format: Online
- Time required: 3 x 1.5hr sessions
- Number of participants: <100
- Cost: £
- All lessons

### PRE-WORKSHOP PREPARATION

- Advertise your course and get participants to register (**1 MONTH BEFORE**).
- Make sure participants have access to kits by posting kits or advising where to source them (**2-3 WEEKS BEFORE**).
- Set up your online meetings on Zoom, Teams or any other platform and give participants joining details (**1 WEEK BEFORE**).
- Ask participants to prepare by downloading the XOD software, beginner's guide and USB drivers (**1 WEEK BEFORE**).
- Ask them to contact you if they have set-up issues. This will save significant time on the day (**1 WEEK BEFORE**).

### HOMEWORK

Ask participants to complete Lesson 3 of the guide at home between sessions 1 and 2 (see **Suggested Structure 1**). Ask participants to complete Lesson 4, Task 7 of the guide at home between sessions 2 and 3.

## Session 1

- 17:00 WELCOME (5MIN)**  
Introduction to the course, the session and the instructors.
- 17:05 LESSON 1 (25MIN)**  
Content from Lesson 1 of the guide in presentation format.
- 17:30 LESSON 2**  
Content from Lesson 2 of the guide via a hands-on session. Live instructor run through (**20MIN**) followed by participants moving to breakout rooms and trying Tasks 1 and 2 (**35MIN**).
- 18:25 ROUND-UP (5MIN)**  
Information about next session and any 'homework'.

## Session 2

- 17:00 WELCOME + RECAP (5MIN)**  
Recap some key information from last session.
- 17:05 LESSON 3 (20MIN)**  
Content from Lesson 3 of the guide in presentation format.
- 17:25 LESSON 4**  
Content from Lesson 4, Tasks 6 and 7 of the guide covered in a hands-on session. Live instructor run through of Task 6 (**15MIN**), participants move to breakout rooms to try Task 6 (**30MIN**), live run through of Task 7 (**15MIN**).
- 18:25 ROUND-UP (5MIN)**  
Information about next session and any 'homework'.

## Session 3

- 17:00 WELCOME + RECAP (5MIN)**  
Recap some key information from last session.
- 17:05 LESSON 4**  
Content from Lesson 4, Task 8 and 9 of the guide covered in a hands-on session. Live instructor run through (**25MIN**) followed by participants moving to breakout rooms and trying Tasks 8 and 9 (**35MIN**).
- 16:05 LESSON 5**  
Content from Lesson 5. Presentation on Expanding Your Capability (**10MIN**). Read Case Studies and discussion (**10MIN**).
- 18:25 ROUND-UP (5MIN)**  
Thank attendees and tell them where to find info and help.



# Suggested Structure 3: One Day In-Person Workshop

## Details

- Format: In-person
- Time required: 1 day (7.5 hr)
- Number of participants: 20-30
- Cost: £££
- All Lessons

### PRE-WORKSHOP PREPARATION

- Set date and book space (**2 MONTHS BEFORE**).
- Advertise your course and get participants to register (**1 MONTH BEFORE**).
- Provide participants with more details, location and agenda (**1 WEEK BEFORE**).
- Set up your work space with 1 kit per person/team and computers if you are providing them (**1-0 DAYS BEFORE**).

## Morning

- 09:00 WELCOME AND LESSON 1**  
Introduction to the course, the session and the instructors (**10MIN**). Help participants set up (**25MIN**). Content from Lesson 1 of the guide in presentation format (**25MIN**).
- 10:00 BREAK**
- 10:30 LESSONS 2 AND 3**  
Content from Lesson 2 of the guide via a hands-on session. Live instructor run through of each task followed by participants trying tasks (**60MIN**). Content from Lesson 3 of the guide in presentation format (**30MIN**).
- 12:00 LUNCH**

## Afternoon

- 13:00 LESSON 4**  
Content from Lesson 4 of the guide covered in a hands-on session. Live instructor run through of each task followed by participants trying tasks (**120MIN**).
- 15:00 BREAK**
- 15:30 LESSON 5**  
Content from Lesson 5 in discussion format. Read Case Studies and discuss (**20MIN**). Presentation on Expanding Your Capability (**20MIN**). Research and plan possible devices (**20MIN**).
- 16:25 ROUND-UP**  
Thank attendees and tell them where to find more information and help (**5MIN**).



# Suggested Structure 4: Two Half-Day In-Person Workshops

## Details

- Format: In-person
- Time required: 2 half days (2 x 3hr)
- Number of participants: 20-30
- Cost: ££
- All Lessons

### PRE-WORKSHOP PREPARATION

- Set date and book space (**2 MONTHS BEFORE**).
- Advertise your course and get participants to register (**1 MONTH BEFORE**).
- Provide participants with more details, location and agenda (**1 WEEK BEFORE**).
- Set up your work space with 1 kit per person/team and computers if you are providing them (**1-0 DAYS BEFORE**).

## Day 1

**13:00 WELCOME AND LESSON 1**  
Introduction to the course, the session and the instructors (**10MIN**). Help participants set up (**25MIN**). Content from Lesson 1 of the guide in presentation format (**25MIN**).

**14:00 BREAK**

**14:20 LESSONS 2 AND 3**  
Content from Lesson 2 of the guide via a hands-on session. Live instructor run through of each task followed by participants trying tasks (**60MIN**). Content from Lesson 3 of the guide in presentation format (**30MIN**).

**15:50 ROUND-UP**  
Thank attendees and tell them where to find more information and help (**5MIN**).

## Day 2

**13:00 WELCOME, RECAP AND LESSON 4**  
Content from Lesson 4, Tasks 6 and 7 of the guide covered in a hands-on session. Live instructor run through of each task followed by participants trying tasks (**60MIN**).

**14:00 BREAK**

**14:20 LESSONS 4 AND 5**  
Content from Lesson 4, Tasks 8 and 9 of the guide covered in a hands-on session. Live instructor run through of each task followed by participants trying tasks (**50MIN**). Content from Lesson 5 in discussion format. Read Case Studies and discuss (**15MIN**). Presentation on Expanding Your Capability (**20MIN**). Research and plan possible devices (**10MIN**).

**15:55 ROUND-UP**  
Thank attendees and tell them where to find more information and help (**5MIN**).



# Pre-Workshop Preparation

In the run-up to your course there are a number of things you will need to prepare. Below is a list of pre-workshop actions you may need to consider.

## SCHEDULE

Depending on your course structure you will need to set a date or dates for your workshop sessions. You will also need to schedule key preparation steps such as booking a space and catering, when to start advertising your course, when registration will close, when to contact participants and when to do any necessary set-up. A suggested schedule is included in the **Preparation Checklist** on the following page.

## HOSTING SPACE

If your workshop is in person you will need a space to host it, for example a meeting room, classroom or workshop space. Ideally this space should have tables for participants to work at and a screen or device for displaying presentations. If participants are not bringing their own laptops the room should also have computers to work from.

If your workshop is online you will need to decide on an online hosting platform. This should have the ability for participants to see the host and their screen. Ideally hosts should also be able to see participants and their screens, as this helps with troubleshooting. Breakout rooms are also useful for larger groups. Examples of platforms include Zoom, Microsoft Teams, Skype and YouTube Live.

## REFRESHMENTS

If your workshop is in person you may need to provide catering, e.g. light refreshments for a half day workshop, lunch for a full day workshop. Alternatively you should provide time in your schedule for participants to bring and eat their own food.

If your online workshop is longer than 1.5 hours you should also schedule in some time for breaks.

## ADVERTISING

Where you advertise your course will depend on your audience. Possible channels include your organisation or department notice boards, newsletters, Twitter or other social media, email and websites.

## REGISTRATION

You should provide a place for participants to register their interest. This could be in person, via email, via an online form such as Google Forms or Survey Monkey, or via an event hosting platform like Eventbrite, Meetup, or your organisation website.



## Pre-Workshop Preparation Continued

**COMMUNICATION** You should remember to communicate efficiently with your participants. Give them a point of contact, provide them with confirmation of registration, information about the course, the agenda, what they need to bring etc. It is also good to contact participants after the workshop to thank them for attending, provide details of where they can find more help or information, provide resources (such as slides or a recording of the workshop) and ask for feedback.

**SET-UP** For in person workshops you may need to set up the room the morning or day before the workshop. Make sure you have the necessary equipment (kits, laptops etc.). For online workshops it is often good to test your meeting system to reduce technical problems when the workshop starts,

## Preparation Checklist

### 2 MONTHS BEFORE

- Set a date
- Make a schedule
- Book a room or decide on an online platform
- Book catering (if required)

### 1 MONTH BEFORE

- Advertise your course. Places to advertise:
  - Organisation/department notice boards
  - Newsletters
  - Twitter/Social Media
  - Email
  - Website
- Provide a way to register
- Tell students if they need to source their own kits

### 1 WEEK BEFORE

- Close registration
- Set up online meeting
- Provide participants with:
  - Location/joining details
  - Agenda
  - List of what they need to bring (laptop etc.)
  - Details of any preparation steps (e.g. download XOD software, Beginner's Guide and USB drivers)
- Make sure you are comfortable with the materials
- Do a practice run through (if desired)

### ON THE DAY

- Prepare workshop space
- Hand out kits (if providing)
- Record workshop (if desired)
- Run workshop

### POST-WORKSHOP

- Prepare questionnaire (if desired)
- Send follow-up email. Possible content:
  - Thank participants for attending
  - Tell them where to find further help and information
  - Tell them about any further training or events
  - Ask them to complete questionnaire
  - Send link to recording
- Review and learn from questionnaire responses

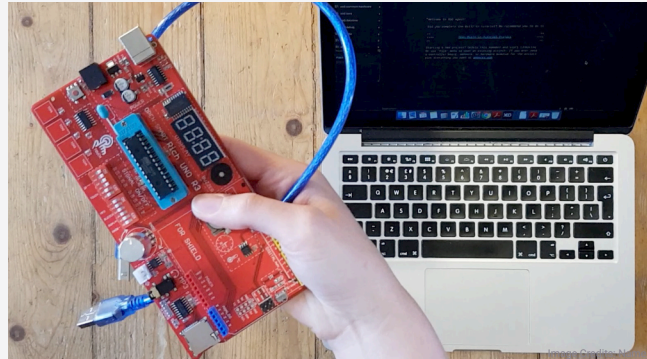


# Teaching Sheets

## Teaching No-Code Programming for Biology

The material taught on the No-Code Programming for Biology course is largely contained within the Beginner's Guide. Whilst students should be able to work through this guide independently, providing a structured course or workshop series for participants offers several advantages. These include:

- Participants are able to learn from and work with their peers
- Teachers can pass on their experience and knowledge
- Participants have a clear time-limit and structure to encourage participation and completion of the course
- Open discussion can inspire different ways of thinking
- Participants can bounce ideas off teachers and peers and ask questions to take their learning further



*Basic equipment for teaching no-code programming: a laptop and an Arduino board.*

As the course teacher or trainer, your job is to guide participants through the materials in a way that is accessible. You should be confident in your knowledge of the course content, be comfortable with public speaking and encouraging learners, and be able to answer some frequently asked questions.

The best way to become comfortable with the course content is to try the activities yourself, and we advise reading through the Beginner's Guide and running through the tasks before giving your workshop.

In this section we provide some additional teaching sheets for each lesson that will help prepare you to teach this material, including an overview of the aims and objectives of each lessons, hints and tips for teaching each one, a list of available resources, and some frequently asked questions.



# Teaching Sheets: Lesson 1

## Aims and Objectives

Lesson 1 of the Beginner's Guide aims to give participants the fundamental knowledge and background they need to complete the rest of the course. By the end of the lesson, participants should be able to:

- Name the different parts of the Grove board and give examples of how they might be used.
- Describe the basic concepts of a microcontroller.
- Describe the steps involved in programming the Arduino board and how information is transmitted in this system.
- Name three of the most common types of electronic communication and explain the difference between them.
- List the pin (port) connections for each of the board's components.
- Recall the different parts of the XOD IDE software and describe what each part is used for.
- Recount the three key terms used in XOD programming and what they mean.
- List the data types used in XOD and give examples of each.

## Key Points to Cover

You can use the powerpoint presentation provided as a base for the content in this lesson. You may want to add or remove certain slides or content from this presentation depending on your audience.

### THE STARTER KIT

- Introduce the Grove board, including a brief explanation of what each of the modules does.

### THE MICROCONTROLLER

- Give a simple explanation of about what a microcontroller is and how it works.
- Introduce the concept of different communication types (analog, digital, I2C).
- Give an overview of the process of programming the Arduino board.

### THE XOD IDE

- Introduce the XOD IDE, including a brief explanation of each of the panes and useful buttons.
- Introduce the XOD concepts of nodes, pins and links.
- Give an overview of the different XOD data types.



# Teaching Sheets: Lesson 2



## Aims and Objectives

Lesson 2 of the Beginner's Guide aims to get participants comfortable with using the XOD software to programme their boards using two examples of simple programmes. By the end of the lesson, participants should be able to:

- Prepare the Biomaker starter kit by downloading the relevant software and drivers, plugging in your board, and opening the XOD IDE.
- Name the different sections of the XOD IDE and understand what they are used for.
- Apply their knowledge of the XOD IDE to perform the following simple tasks: add a node, change pin settings, connect nodes, add a library.
- Use the XOD IDE to upload programmes to your board.
- Use the XOD IDE to clear programmes from your board.
- Use three of the inbuilt components on the Grove board: the LED, the buzzer and the button.
- Understand how to troubleshoot your programme and find additional help.
- Understand how input and output devices can be used together to build simple devices.

## Key Points to Cover

Use the powerpoint presentation provided as a base for the content in this lesson. You may want to add or remove certain slides or content from this presentation depending on your audience. You can either 1) demonstrate both tasks at once with participants trying both tasks at the end, or 2) demonstrate each task in turn with participants practicing after each demonstration. For online workshops we suggest option 1, for in person workshops we suggest option 2. When demonstrating, try to show both how you build the programme on your computer screen, using a projector or share screen, and what happens to your board when you upload, via a physical demonstration or a video.

### TESTING YOUR BOARD

- Demonstrate Task 1. This will demonstrate much of what they have just learned in Lesson 1.
- Task 1 uses the *led*, *button* and *not* nodes to control the onboard LED using the button.

### INPUTS AND OUTPUTS

- Demonstrate Task 2, which replaces the LED with a buzzer, and adds a potentiometer to control the pitch.

# Teaching Sheets: Lesson 3

## Aims and Objectives

Lesson 3 of the Beginner's Guide aims to demonstrate the use of some of the most useful nodes in XOD. These nodes will be used often in the following chapters, and it is good to have an understanding of how they work before proceeding. By the end of the lesson, participants should be able to:

- Explain the functions of the following XOD nodes: *tweak*, *watch*, *flip-n-times*, *flip-flop*, *clock*, *count*, *concat*, *join*, *format-number*.
- Apply their knowledge of these nodes to start building simple programmes.
- Use the XOD IDE to create and save a new project.
- Use the XOD IDE to 'upload and debug' programmes, allowing you to watch and edit their programme live.
- Use two more of the inbuilt components on the Grove board: the temperature and humidity sensor and the air pressure sensor.
- Build and compare different versions of a programme to achieve different functions and outcomes.
- Experiment with the programmes they have built by changing parameters and exploring new nodes
- Understand where to find more information about the basic nodes available in XOD



## Key Points to Cover

We suggest running through the tasks in Lesson 3 by simply demonstrating each task. The powerpoint slides include a title slide to go over the basics for each set of nodes, and a video slide with a demonstration of the task.

### TWEAK AND WATCH NODES

- *tweak* and *watch* nodes are used alongside the XOD 'Debugger' to edit and watch programmes in real-time.
- They are useful for trouble shooting and checking that programmes are running correctly.
- Task 3 uses a *tweak* node to initiate readings from the temperature and humidity sensor, and *watch* nodes to view the results.

### FLIP, CLOCK AND COUNT NODES

- These nodes are useful for controlling and monitoring the timing of you programme.
- Task 4 demonstrates how the *flip-n-times*, *flip-flop* and *clock* nodes can be used to control the LED in different ways, and how the *count* and *watch* nodes can be used monitor the programmes progress.

### CONCAT, JOIN AND FORMAT NUMBER

- These nodes are useful for formatting text and number outputs from programmes.
- Task 5 demonstrates how to use these nodes to format the outputs from the air-pressure sensor.

# Teaching Sheets: Lesson 4

## Aims and Objectives

Lesson 4 of the Beginner's Guide aims to give participants the skills they need to start building more complex programmes in XOD. These skills should set participants up to start thinking about how to make their own programmes and devices. By the end of the lesson, participants should be able to:

- Describe the function of XOD terminal nodes and how they are used.
- Create new nodes in XOD by combining existing and terminal nodes.
- Test and use the new nodes you have created in programmes.
- Describe the function of buses, their advantages, and how to use them.
- Use maths and logic nodes to create logic programmes in XOD.
- Recall at least two different methods for creating sequences in XOD.
- Implement programming loops in XOD using the *defer* node.
- Use the remaining components on the Grove board: the sound sensor, light sensor, 3-axis acceleration sensor and the OLED screen.
- Programme the OLED screen to display graphics such as text and shapes.
- Recall how to document your nodes correctly, including describing the node and it's pins and adding comment boxes.
- Recall how to publish nodes, or collections of patches a library.

## Key Points to Cover

You can use the powerpoint presentation provided as a base to demonstrate and practice each task in turn.

### CREATING NEW NODES

- Programmes can be simplified by encapsulating sections into new nodes using *input* and *output* terminals.
- In Task 6 participants create a new node to write text on the OLED screen.

### USING BUSES

- Buses link different parts of the programme 'invisibly' and are useful for tidying up complex programmes.
- Task 7 demonstrates how buses work by creating a game using the 3-axis acceleration sensor and screen.
- If you are short on time, you can modify the node created in Task 6 to demonstrate the use of buses instead.

### LOGIC PROGRAMMES

- You can use logic nodes like IF, OR, AND, to create logic programmes that covert inputs to outputs.
- Task 8 uses logic nodes to return different text on the screen depending on the surrounding light intensity.

### SEQUENCES AND LOOPS

- There are a many ways to create sequences in XOD, and Task 9 demonstrates two of these.
- Task 9 also demonstrates how to create loops using the *defer* node to play a simple tune on the buzzer.



# Teaching Sheets: Lesson 5

## Aims and Objectives

Lesson 5 of the Beginner's Guide aims to equip participants with the knowledge of where to go next, how to start adding hardware to their boards, and where to find help and advice for their own projects. By the end of the lesson, participants should be able to:

- Recall where to find additional components compatible with the Grove board.
- Recognise the different ways to connect new components to the Grove board.
- Locate compatible XOD nodes for new devices.
- Outline some examples of how these skills can be applied to biological research.
- Recall where to find additional information and help with building their own devices.

## Key Points to Cover

You can use the powerpoint presentation provided as a base for the content in this lesson.

### EXPANDING YOUR CAPACITY

- There are a wide variety of components that can be added to the board to create custom devices.
- There are 'plug-and-play' components and components you need to wire, the slides and the guide provide information on how to attach different types of component to the board and where to buy them from.
- You can find nodes for many devices on the XOD website and forum, or convert Arduino libraries to XOD.
- The Arduino IDE can be a useful tool for taking your skills further

### CASE STUDIES

- The guide contains four case studies of custom devices used for biological research.
- Initiate a discussion around the case studies as a basis for encouraging participants to think about what devices might be useful for their own research.
- If you have time, encourage participants to start planning their own devices and think about what hardware and programming skills they might need to achieve that.

