

contents in detail

introduction	xxi
why this book?.....	xxi
is this book for you?.....	xxi
how does this book work?	xxi
the discoveries.....	xxi
what to expect in each chapter.....	xxii
the companion website.....	xxii
conclusion.....	xxii

PART I GETTING STARTED

1	
preparing your EV3 set	3
what's in the box?.....	3
the EV3 brick.....	3
sorting Technic elements.....	5
the mission pad.....	5
controlling your robot.....	6
downloading and installing the EV3 programming software.....	6
conclusion.....	7
2	
building your first robot	9
using the building instructions.....	9
building the EXPLOR3R.....	10
output ports, input ports, and cables	20
navigating the EV3 brick	20
turning the EV3 on and off.....	21
selecting and running programs	22
making your robot move with the remote control.....	22
conclusion.....	23
3	
creating and modifying programs	25
a quick first program.....	25
creating a basic program	27
1. programming palette.....	27
2. start block.....	27
3. programming canvas.....	27
4. hardware page.....	28

projects and programs.....	29
5. file organization.....	29
6. toolbar.....	30
7. content editor.....	32
building the official EV3 robots and bonus models.....	32
conclusion.....	33

4

working with programming blocks: action blocks.....	35
how do programming blocks work?.....	35
the move steering block.....	35
the move steering block in action.....	35
understanding modes and settings.....	37
making accurate turns.....	39
<i>Discovery #1: Accelerate!</i>	39
<i>Discovery #2: Precise Turns!</i>	39
<i>Discovery #3: Move That Bot!</i>	39
<i>Discovery #4: RoboSpeller!</i>	40
the sound block.....	40
understanding the sound block settings.....	40
seeing the sound block in action.....	41
<i>Discovery #5: Which Direction Did You Say?</i>	41
<i>Discovery #6: Be the DJ!</i>	42
the display block.....	42
understanding the display block settings.....	42
the display block in action.....	43
<i>Discovery #7: Subtitles!</i>	44
<i>Discovery #8: W8 for the EXPLOR3R!</i>	44
the brick status light block.....	44
<i>Discovery #9: Traffic Light!</i>	45
the on and off modes in move blocks.....	45
<i>Discovery #10: Drive Time Radio!</i>	46
move tank, large motor, and medium motor blocks.....	46
further exploration.....	46
<i>Discovery #11: Circle Time!</i>	47
<i>Discovery #12: Navigator!</i>	47
<i>Discovery #13: RoboDancer</i>	48
<i>Design Discovery #1: RoboCleaner!</i>	48
<i>Design Discovery #2: Art with the EXPLOR3R!</i>	48

5

waiting, repeating, my blocks, and multitasking.....	49
the wait block.....	49
using the wait block settings.....	49
seeing the wait block in action.....	49

understanding the WaitDisplay program.....	50
<i>Discovery #14: Leave a Message!</i>	50
<i>Discovery #15: Board Game Timer!</i>	50
the loop block.....	50
using the loop block.....	50
seeing the loop block in action.....	51
using loop blocks within loop blocks.....	51
<i>Discovery #16: Guard the Room</i>	52
<i>Discovery #17: Triangle!</i>	53
making your own blocks: the my block.....	53
creating my blocks.....	53
using my blocks in programs.....	53
editing my blocks.....	53
managing my blocks in projects.....	53
<i>Discovery #18: My Square!</i>	56
<i>Discovery #19: My Tune!</i>	56
multitasking.....	56
using multiple start blocks.....	56
splitting the sequence wire.....	56
avoiding resource conflicts.....	57
further exploration.....	57
<i>Discovery #20: Let's Multitask!</i>	57
<i>Discovery #21: Singletasking!</i>	57
<i>Discovery #22: Complex Figures!</i>	58
<i>Design Discovery #3: Mr. EXPLOR3R!</i>	58

PART II PROGRAMMING ROBOTS WITH SENSORS

6

understanding sensors.....	61
what are sensors?.....	62
understanding the sensors in the EV3 set.....	62
understanding the touch sensor.....	62
creating the bumper with the touch sensor.....	62
viewing sensor values.....	66
programming with sensors.....	66
sensors and the wait block.....	66
<i>Discovery #23: Hello and Goodbye!</i>	67
<i>Discovery #24: Avoid Obstacles and a Bad Mood!</i>	67
<i>Discovery #25: Easy Push!</i>	68
sensors and the loop block.....	68
<i>Discovery #26: Happy Tunes!</i>	69
sensors and the switch block.....	69
<i>Discovery #27: Stay or Move?</i>	71
<i>Discovery #28: Difficult Decisions!</i>	71
understanding compare, change, and measure mode.....	73

further exploration.....	74
<i>Discovery #29: Choosing Directions!</i>	74
<i>Discovery #30: Wait, Loop, or Switch?</i>	74
<i>Discovery #31: Brick Buttons!</i>	74
<i>Design Discovery #4: Intruder Alarm!</i>	74
<i>Design Discovery #5: Light Switch!</i>	74

7

using the color sensor.....	75
attaching the color sensor.....	75
color mode.....	77
staying inside a colored line.....	77
<i>Design Discovery #6: Bulldozer!</i>	78
following a line.....	79
the switch block in measure mode.....	80
<i>Discovery #32: Create Your Own Track!</i>	81
<i>Discovery #33: Stop at the Blue Sign!</i>	81
<i>Discovery #34: Say Color!</i>	81
reflected light intensity mode.....	81
<i>Discovery #35: Super Reflector!</i>	81
setting the threshold value.....	82
comparing sensor values with a threshold.....	82
following a line more smoothly.....	83
ambient light intensity mode.....	85
measuring ambient light intensity.....	85
a morse code program.....	85
<i>Discovery #36: Morning Alarm!</i>	86
further exploration.....	86
<i>Discovery #37: Color Tag!</i>	87
<i>Discovery #38: Fingerprint Scanner!</i>	87
<i>Discovery #39: Color Pattern!</i>	87
<i>Discovery #40: Obstacles on the Line!</i>	87
<i>Discovery #41: Crazy Track!</i>	88
<i>Design Discovery #7: Doorbell!</i>	88
<i>Design Discovery #8: Safe Deposit!</i>	88

8

using the infrared sensor.....	89
proximity mode.....	89
avoiding obstacles.....	90
combining sensors.....	90
<i>Discovery #42: Close Up!</i>	90
<i>Discovery #43: Three Sensors!</i>	90
remote mode.....	92
<i>Discovery #44: Unlock the Remote!</i>	92
beacon proximity mode.....	93

beacon heading mode	93
<i>Discovery #45: Smooth Follower!</i>	94
combining sensor operation modes.....	95
further exploration.....	95
<i>Discovery #46: Follow Me!</i>	95
<i>Discovery #47: Sonar Sounds!</i>	96
<i>Design Discovery #9: Railroad Crossing!</i>	96
<i>Design Discovery #10: Foolproof Alarm!</i>	96
9	
using the brick buttons and rotation sensors	97
using the brick buttons	97
<i>Discovery #48: Long Message!</i>	97
<i>Discovery #49: Custom Menu!</i>	97
using the rotation sensor	98
motor position	98
resetting the motor position.....	99
rotational speed	99
<i>Discovery #50: Back to the Start!</i>	100
<i>Discovery #51: Colored Speed!</i>	100
understanding speed regulation.....	101
seeing speed regulation in action.....	101
stopping a stalled motor	101
further exploration.....	102
<i>Discovery #52: Brick Buttons Remote!</i>	102
<i>Discovery #53: Low Speed Obstacle Detection!</i>	102
<i>Design Discovery #11: Automatic House!</i>	102

PART III ROBOT-BUILDING TECHNIQUES

10	
building with beams, axles, connector blocks, and motors.....	105
using beams and frames.....	106
extending beams	106
using frames.....	106
using beams to reinforce structures.....	107
using angled beams	107
<i>Discovery #54: Bigger Triangles!</i>	108
using the LEGO unit grid.....	108
<i>Discovery #55: Angled Combinations!</i>	110
using axles and cross holes	110
using connector blocks.....	111
extending axles	111
connecting parallel beams	111
connecting beams at right angles.....	111
securing parallel beams.....	111
<i>Discovery #56: Constructive Connectors!</i>	113

using half LEGO units.....	114
<i>Discovery #57: Half-Unit Beams!</i>	114
using thin elements.....	114
creating flexible structures.....	114
building with motors and sensors.....	115
building with the large motor.....	115
building with the medium motor.....	118
building with sensors.....	119
miscellaneous elements.....	119
further exploration.....	119
<i>Design Discovery #12: Tank Drive!</i>	119
<i>Design Discovery #13: Tabletop Cleaner!</i>	120
<i>Design Discovery #14: Curtain Opener!</i>	120

11

building with gears	121
gearing essentials.....	121
<i>Discovery #58: Observing Gears!</i>	122
taking a closer look at gears.....	122
calculating the gear ratio for two gears.....	123
decreasing and increasing rotational speed.....	123
<i>Discovery #59: Gearing Math!</i>	124
what is torque?.....	124
creating longer gear trains.....	125
<i>Discovery #60: Predictable Movement</i>	127
<i>Discovery #61: Compound Direction!</i>	127
friction and backlash.....	128
using the gears in the EV3 set.....	128
working with the unit grid.....	129
using bevel and double-bevel gears.....	130
<i>Discovery #62: Perpendicular Options!</i>	133
<i>Discovery #63: Strong Gear Trains!</i>	133
using knob wheels.....	133
using worm gears.....	133
<i>Discovery #64: Worm Drive!</i>	134
constructing sturdy gear trains.....	134
bracing gears with beams.....	134
preventing axles from twisting.....	135
reversing direction of rotation.....	135
building with gears and EV3 motors.....	135
further exploration.....	137
<i>Design Discovery #15: Dragster!</i>	137
<i>Design Discovery #16: SnailBot!</i>	137
<i>Design Discovery #17: Chimney Climber!</i>	137
<i>Design Discovery #18: Turntable!</i>	138
<i>Design Discovery #19: Robotic Arm!</i>	138

PART IV VEHICLE AND ANIMAL ROBOTS

12

Formula EV3: a racing robot	141
building the Formula EV3 Race Car	142
driving and steering.....	163
creating my blocks for steering	163
testing the my blocks	166
creating a remote control program.....	166
racing autonomously	168
further exploration.....	168
<i>Discovery #65: Overshoot Experiment!</i>	168
<i>Discovery #66: Night Racing!</i>	168
<i>Discovery #67: Wired Gas Pedal!</i>	169
<i>Discovery #68: Blinking Rear Light!</i>	169
<i>Discovery #69: Crash Detection!</i>	169
<i>Design Discovery #20: Racing Faster!</i>	170
<i>Design Discovery #21: Car Upgrade!</i>	170

13

ANTY: the robotic ant.....	171
understanding the walking mechanism.....	172
building ANTY.....	173
making ANTY walk.....	190
creating the opposite my block.....	190
avoiding obstacles	190
programming behavior	191
finding food.....	191
sensing the environment.....	191
further exploration.....	194
<i>Discovery #70: Remote Control!</i>	194
<i>Discovery #71: Night Creature!</i>	194
<i>Discovery #72: Hungry Robots!</i>	194
<i>Design Discovery #22: Robotic Spider!</i>	194
<i>Design Discovery #23: Antennae!</i>	195
<i>Design Discovery #24: Creepy Claws!</i>	195

PART V CREATING ADVANCED PROGRAMS

14

using data wires.....	199
building SK3TCHBOT	200
getting started with data wires.....	210
<i>Discovery #73: Sound in the Distance!</i>	210

working with data wires	211
seeing the value in a data wire	211
deleting a data wire	212
data wires across a program	212
using multiple data wires	212
repeating blocks with data wires	213
<i>Discovery #74: Bar Graph!</i>	213
<i>Discovery #75: Extended Graph!</i>	214
data wire types	214
numeric data wire	214
logic data wire	214
text data wire	214
<i>Discovery #76: Smooth Stop!</i>	214
numeric array and logic array	215
type conversion	215
using sensor blocks	217
measure mode	217
compare mode	218
<i>Discovery #77: Sensor Throttle!</i>	219
<i>Discovery #78: My Port View!</i>	219
<i>Discovery #79: Compare Size!</i>	219
data wire value range	219
advanced features of flow blocks	220
data wires and the wait block	220
data wires and the loop block	220
<i>Discovery #80: IR Acceleration!</i>	221
data wires and the switch block	221
the loop interrupt block	223
<i>Discovery #81: Interrupting Interrupts!</i>	225
further exploration	225
<i>Discovery #82: Sensor Practice!</i>	225
<i>Discovery #83: Power vs. Speed!</i>	225
<i>Discovery #84: Real Direction!</i>	226
<i>Discovery #85: SK3TCHBOT Is Watching You!</i>	226
<i>Discovery #86: Oscilloscope!</i>	226
<i>Design Discovery #25: Bionic Hand!</i>	226

15

using data operations blocks and my blocks with data wires..... 227

using data operations blocks	227
the math block	228
<i>Discovery #87: 100% Math!</i>	228
<i>Discovery #88: Added Value!</i>	230
<i>Discovery #89: Infrared Speed!</i>	230
<i>Discovery #90: Double Infrared Speed!</i>	230
<i>Discovery #91: Gain Control!</i>	230
<i>Discovery #92: Direction Control!</i>	230

the random block.....	231
<i>Discovery #93: Random Frequency!</i>	231
the compare block.....	232
<i>Discovery #94: Random Motor and Speed!</i>	232
the logic operations block.....	233
<i>Discovery #95: Logic Sensors!</i>	234
<i>Discovery #96: Wait for Three Sensors!</i>	234
the range block.....	234
the round block.....	235
the text block.....	235
<i>Discovery #97: Countdown!</i>	236
creating my blocks with data wires.....	236
a my block with input.....	236
editing my blocks.....	239
<i>Discovery #98: My Unit!</i>	239
<i>Discovery #99: Enhanced Display!</i>	239
a my block with output.....	240
<i>Discovery #100: Proximity Average!</i>	241
<i>Discovery #101: Proximity Rate!</i>	241
a my block with input and output.....	242
<i>Discovery #102: Circle Math!</i>	243
strategies for making my blocks.....	243
starting points for my blocks.....	243
sharing my blocks between projects.....	243
further exploration.....	243
<i>Discovery #103: Is It an Integer?</i>	244
<i>Discovery #104: Double Stalled!</i>	244
<i>Discovery #105: Reflex Test!</i>	244
<i>Design Discovery #26: Robot Clock!</i>	244

16

using constants and variables.....	245
using constants.....	245
using variables.....	245
defining a variable.....	246
using the variable block.....	246
<i>Discovery #106: Old vs. New!</i>	248
<i>Discovery #107: Previous vs. New!</i>	248
changing and incrementing variable values.....	249
initializing variables.....	249
calculating an average.....	250
further exploration.....	251
<i>Discovery #108: Counting Up and Down!</i>	251
<i>Discovery #109: Limited Average!</i>	251
<i>Discovery #110: Random Verification!</i>	251
<i>Discovery #111: Closest Approach!</i>	252
<i>Design Discovery #27: Customer Counter!</i>	252

17		
playing games on the EV3		253
step 1: creating basic drawings		254
my block #1: clear		254
my block #2: coordinates		254
completing the basic program		254
step 2: adding pencil controls		255
moving the pencil without drawing		255
turning the pencil into an eraser		255
clearing the screen		257
setting the pencil size		257
<i>Discovery #112: Robot Artist!</i>		259
<i>Discovery #113: Force Feedback!</i>		259
<i>Discovery #114: Pencil Pointer!</i>		259
further exploration		259
<i>Discovery #115: Arcade Game!</i>		259
<i>Discovery #116: Brain Trainer!</i>		260
<i>Design Discovery #28: Plotter!</i>		260

PART VI MACHINE AND HUMANOID ROBOTS

18		
the SNATCH3R: the autonomous robotic arm		263
understanding the grabber		263
the grabber mechanism		265
the lifting mechanism		265
building the SNATCH3R		266
controlling the grabber		299
my block #1: grab		299
my block #2: reset		299
my block #3: release		299
creating the remote control program		300
<i>Discovery #117: Extended Remote!</i>		301
<i>Discovery #118: Remote Speed Control!</i>		301
troubleshooting the grabber		301
searching for the IR beacon		301
building the IR bug		301
my block #4: search		303
<i>Discovery #119: Signal Verification!</i>		307
creating the final program		307
further exploration		308
<i>Discovery #120: Keeping Busy!</i>		309
<i>Discovery #121: Path Finder!</i>		309
<i>Discovery #122: Proximity Finder!</i>		309
<i>Design Discovery #29: Excavator!</i>		309

19

LAVA R3X: the humanoid that walks and talks	311
building the legs.....	312
making the robot walk	330
my block #1: reset.....	330
my block #2: return.....	330
my block #3: onsync.....	332
my block #4: left.....	334
taking the first steps.....	334
<i>Discovery #123: Walk My Block!</i>	335
<i>Discovery #124: Reverse!</i>	335
<i>Discovery #125: Right Turn!</i>	335
building the head and arms.....	335
controlling the head and arms.....	344
my block #5: head.....	344
avoiding obstacles and responding to handshakes	344
further exploration.....	347
<i>Discovery #126: Dancing Robots!</i>	347
<i>Discovery #127: What's the Difference?</i>	348
<i>Discovery #128: Robot Coach!</i>	348
<i>Discovery #129: Robot Follower!</i>	348
<i>Discovery #130: Synchronized Pace!</i>	348
<i>Discovery #131: Remote Walk!</i>	348
<i>Discovery #132: Tamagotchi!</i>	349
<i>Design Discovery #30: Biped Robot!</i>	349

A

troubleshooting programs, the EV3 brick, and wireless connections	351
troubleshooting compilation errors.....	351
missing my blocks	351
errors in programming blocks	351
missing variable definitions	352
troubleshooting a running program.....	352
troubleshooting the EV3	354
using the hardware page.....	354
solving problems with the USB connection.....	355
restarting the EV3 brick.....	355
updating the EV3 firmware.....	355
avoiding data loss using a microSD card	356
programming the EV3 wirelessly.....	356
using Bluetooth to download programs to the EV3	356
using Wi-Fi to download programs to the EV3	358
choosing between Bluetooth and Wi-Fi.....	358
summary.....	358

B	
creating on brick programs	359
creating, saving, and running an on brick program	359
adding blocks to the loop	360
configuring a block's setting	360
running a program	360
saving and opening a program	361
using the on brick programming blocks	361
importing on brick programs	361
summary	363
index	365