```
import tensorflow as tf
from tensorflow.keras import layers
import matplotlib.pyplot as plt
import numpy as np
import time

# Load and preprocess the CIFAR-10 dataset
(train_images, train_labels), (_, _) =
tf.keras.datasets.cifar10.load_data()
train_images = train_images.astype('float32')
train_images = (train_images - 127.5) / 127.5  # Normalize the images
to [-1, 1]

def build_generator():
    model = tf.keras.Sequential()
    model.add(layers.Dense(8*8*256, use_bias=False,
input_shape=(100,)))
    model.add(layers.BatchNormalization())
    model.add(layers.LeakyReLU())

    model.add(layers.Reshape((8, 8, 256)))
    model.add(layers.Conv2DTranspose(128, (5, 5), strides=(1, 1),
padding='same', use_bias=False))
    model.add(layers.BatchNormalization())
    model.add(layers.LeakyReLU())

    model.add(layers.Conv2DTranspose(64, (5, 5), strides=(2, 2),
padding='same', use_bias=False))
    model.add(layers.BatchNormalization())
    model.add(layers.LeakyReLU())

    model.add(layers.Conv2DTranspose(3, (5, 5), strides=(2, 2),
padding='same', use_bias=False, activation='tanh'))
    return model

def build_discriminator():
    model = tf.keras.Sequential()
    model.add(layers.Conv2D(64, (5, 5), strides=(2, 2),
padding='same', input_shape=[32, 32, 3]))
    model.add(layers.LeakyReLU())
    model.add(layers.Dropout(0.3))

    model.add(layers.Conv2D(128, (5, 5), strides=(2, 2),
padding='same'))
    model.add(layers.LeakyReLU())
    model.add(layers.Dropout(0.3))

    model.add(layers.Flatten())
    model.add(layers.Dense(1, activation='sigmoid'))
    return model
```

```
# Define loss function and optimizers
cross_entropy = tf.keras.losses.BinaryCrossentropy(from_logits=True)

def discriminator_loss(real_output, fake_output):
    real_loss = cross_entropy(tf.ones_like(real_output), real_output)
    fake_loss = cross_entropy(tf.zeros_like(fake_output), fake_output)
    total_loss = real_loss + fake_loss
    return total_loss

def generator_loss(fake_output):
    return cross_entropy(tf.ones_like(fake_output), fake_output)

generator_optimizer = tf.keras.optimizers.Adam(1e-4)
discriminator_optimizer = tf.keras.optimizers.Adam(1e-4)

EPOCHS = 100
noise_dim = 100
num_examples_to_generate = 16
seed = tf.random.normal([num_examples_to_generate, noise_dim])

@tf.function
def train_step(images):
    noise = tf.random.normal([BATCH_SIZE, noise_dim])

    with tf.GradientTape() as gen_tape, tf.GradientTape() as
disc_tape:
        generated_images = generator(noise, training=True)

        real_output = discriminator(images, training=True)
        fake_output = discriminator(generated_images, training=True)

        gen_loss = generator_loss(fake_output)
        disc_loss = discriminator_loss(real_output, fake_output)

    gradients_of_generator = gen_tape.gradient(gen_loss,
generator.trainable_variables)
    gradients_of_discriminator = disc_tape.gradient(disc_loss,
discriminator.trainable_variables)

    generator_optimizer.apply_gradients(zip(gradients_of_generator,
generator.trainable_variables))

discriminator_optimizer.apply_gradients(zip(gradients_of_discriminator
, discriminator.trainable_variables))

    return gen_loss, disc_loss

# Create and compile models
generator = build_generator()
discriminator = build_discriminator()
```

```
generator.summary()
```

```
Model: "sequential_4"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_4 (Dense)             (None, 16384)             1638400

 batch_normalization_6 (Bat  (None, 16384)             65536
 chNormalization)

 leaky_re_lu_10 (LeakyReLU)  (None, 16384)             0

 reshape_2 (Reshape)         (None, 8, 8, 256)         0

 conv2d_transpose_6 (Conv2D  (None, 8, 8, 128)         819200
 Transpose)

 batch_normalization_7 (Bat  (None, 8, 8, 128)         512
 chNormalization)

 leaky_re_lu_11 (LeakyReLU)  (None, 8, 8, 128)         0

 conv2d_transpose_7 (Conv2D  (None, 16, 16, 64)        204800
 Transpose)

 batch_normalization_8 (Bat  (None, 16, 16, 64)        256
 chNormalization)

 leaky_re_lu_12 (LeakyReLU)  (None, 16, 16, 64)        0

 conv2d_transpose_8 (Conv2D  (None, 32, 32, 3)         4800
 Transpose)

=================================================================
Total params: 2733504 (10.43 MB)
Trainable params: 2700352 (10.30 MB)
Non-trainable params: 33152 (129.50 KB)
_________________________________________________________________
```

```
discriminator.summary()
```

```
Model: "sequential_5"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_4 (Conv2D)           (None, 16, 16, 64)        4864

 leaky_re_lu_13 (LeakyReLU)  (None, 16, 16, 64)        0
```

```
 dropout_4 (Dropout)         (None, 16, 16, 64)        0

 conv2d_5 (Conv2D)           (None, 8, 8, 128)         204928

 leaky_re_lu_14 (LeakyReLU)  (None, 8, 8, 128)         0

 dropout_5 (Dropout)         (None, 8, 8, 128)         0

 flatten_2 (Flatten)         (None, 8192)              0

 dense_5 (Dense)             (None, 1)                 8193

=================================================================
Total params: 217985 (851.50 KB)
Trainable params: 217985 (851.50 KB)
Non-trainable params: 0 (0.00 Byte)
_________________________________________________________________
```

```python
# Initialize the models
generator = build_generator()
discriminator = build_discriminator()

# Build the models to ensure all layers are initialized
generator.build(input_shape=(None, 100))  # Adjust the input shape
based on your noise dimension
discriminator.build(input_shape=(None, 32, 32, 3))  # Adjust input
shape to match CIFAR-10 image dimensions

# Create and compile models after building
generator_optimizer = tf.keras.optimizers.Adam(1e-4)
discriminator_optimizer = tf.keras.optimizers.Adam(1e-4)

# Configure the optimizers with the variables
generator_optimizer.build(generator.trainable_variables)
discriminator_optimizer.build(discriminator.trainable_variables)

@tf.function
def train_step(images):
    noise = tf.random.normal([BATCH_SIZE, noise_dim])
    with tf.GradientTape() as gen_tape, tf.GradientTape() as
disc_tape:
        generated_images = generator(noise, training=True)
        real_output = discriminator(images, training=True)
        fake_output = discriminator(generated_images, training=True)
        gen_loss = generator_loss(fake_output)
        disc_loss = discriminator_loss(real_output, fake_output)
    gradients_of_generator = gen_tape.gradient(gen_loss,
generator.trainable_variables)
    gradients_of_discriminator = disc_tape.gradient(disc_loss,
discriminator.trainable_variables)
```

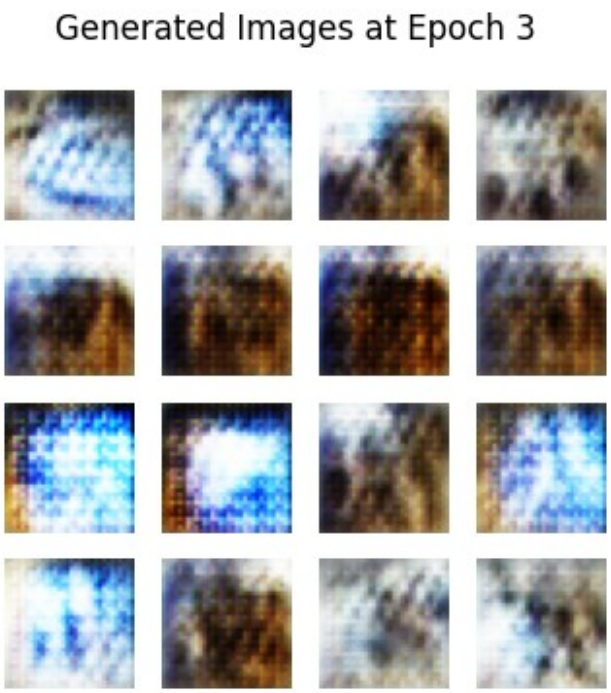
```
    generator_optimizer.apply_gradients(zip(gradients_of_generator,
generator.trainable_variables))

discriminator_optimizer.apply_gradients(zip(gradients_of_discriminator
, discriminator.trainable_variables))
    return gen_loss, disc_loss


# Prepare the dataset for training
BUFFER_SIZE = 20000
BATCH_SIZE = 32

train_dataset =
tf.data.Dataset.from_tensor_slices(train_images).shuffle(BUFFER_SIZE).
batch(BATCH_SIZE)


def generate_and_save_images(model, epoch, test_input):
    predictions = model(test_input, training=False)
    fig = plt.figure(figsize=(4, 4))

    for i in range(predictions.shape[0]):
        plt.subplot(4, 4, i+1)
        plt.imshow((predictions[i, :, :, :] + 1) / 2)  # Adjusting
normalization for display
        plt.axis('off')

    plt.suptitle(f"Generated Images at Epoch {epoch}")
    plt.show()  # Ensures the image is displayed in Jupyter Notebook
    plt.savefig(f'image_at_epoch_{epoch:04d}.png')  # Save each
epoch's generated images

def train(dataset, epochs):
    for epoch in range(epochs):
        start_time = time.time()  # Start timing the epoch
        for image_batch in dataset:
            gen_loss, disc_loss = train_step(image_batch)  # Capture
losses from train_step

        # Generate and display images
        generate_and_save_images(generator, epoch + 1, seed)

        end_time = time.time()  # End timing the epoch
        print(f"Epoch {epoch+1}/{EPOCHS} - Generator Loss:
{gen_loss.numpy():.4f}, Discriminator Loss: {disc_loss.numpy():.4f} -
Time Taken: {end_time - start_time:.2f} sec")


# Start the training process
train(train_dataset, EPOCHS)
```

Generated Images at Epoch 1

```
Epoch 1/100 - Generator Loss: 0.9341, Discriminator Loss: 1.2777 -
Time Taken: 169.87 sec

<Figure size 640x480 with 0 Axes>
```

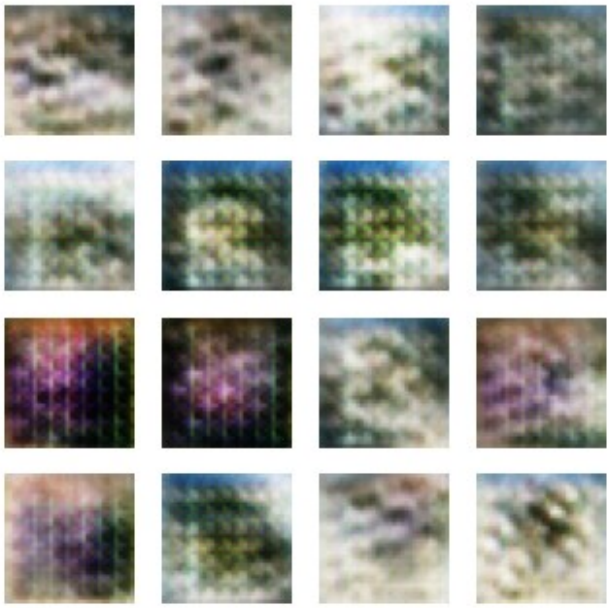
Generated Images at Epoch 2

```
Epoch 2/100 - Generator Loss: 1.0615, Discriminator Loss: 1.2185 -
Time Taken: 164.02 sec

<Figure size 640x480 with 0 Axes>
```




```
Epoch 3/100 - Generator Loss: 0.8092, Discriminator Loss: 1.6920 -
Time Taken: 158.22 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 4



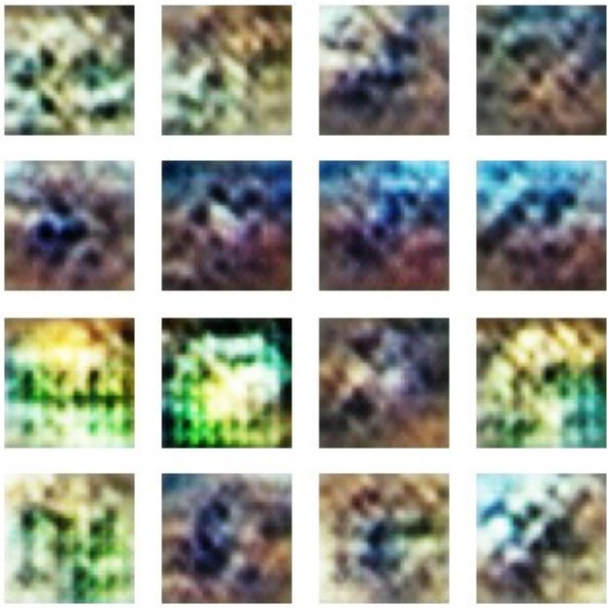
```
Epoch 4/100 - Generator Loss: 0.7361, Discriminator Loss: 1.2987 -
Time Taken: 157.09 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 5

```
Epoch 5/100 - Generator Loss: 1.2502, Discriminator Loss: 1.1228 -
Time Taken: 156.99 sec

<Figure size 640x480 with 0 Axes>
```


```
Epoch 6/100 - Generator Loss: 0.9812, Discriminator Loss: 1.4240 -
Time Taken: 156.94 sec

<Figure size 640x480 with 0 Axes>
```

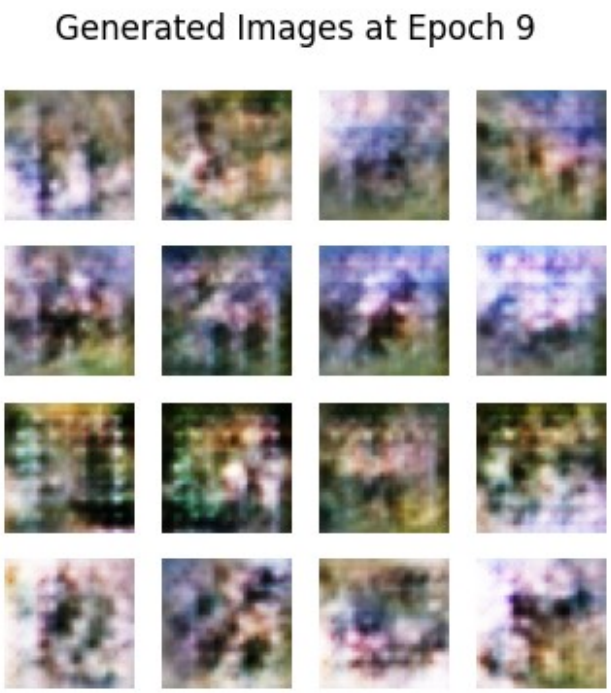
Generated Images at Epoch 7



```
Epoch 7/100 - Generator Loss: 0.7597, Discriminator Loss: 1.5265 -
Time Taken: 159.94 sec

<Figure size 640x480 with 0 Axes>
```

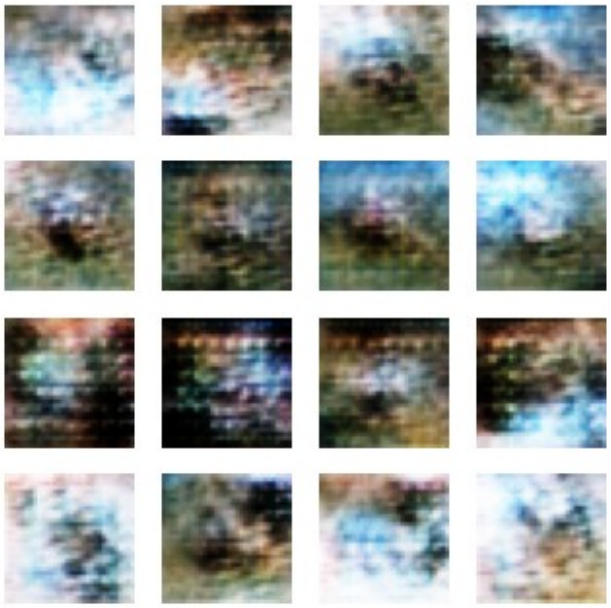
Generated Images at Epoch 8

```
Epoch 8/100 - Generator Loss: 1.0404, Discriminator Loss: 1.1523 -
Time Taken: 159.51 sec

<Figure size 640x480 with 0 Axes>
```



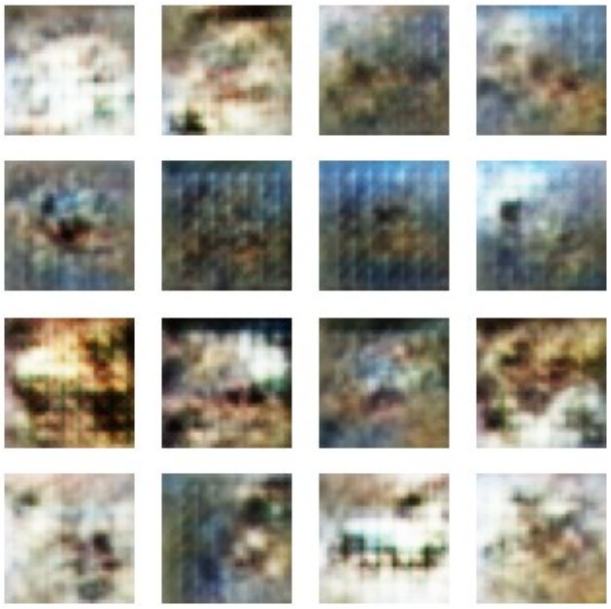

```
Epoch 9/100 - Generator Loss: 1.2566, Discriminator Loss: 1.0486 -
Time Taken: 156.18 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 10

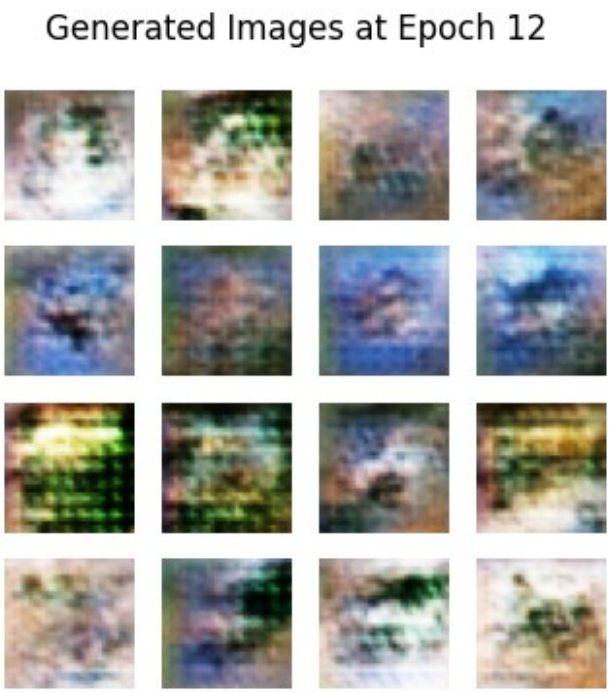


```
Epoch 10/100 - Generator Loss: 1.1700, Discriminator Loss: 1.0708 -
Time Taken: 156.57 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 11

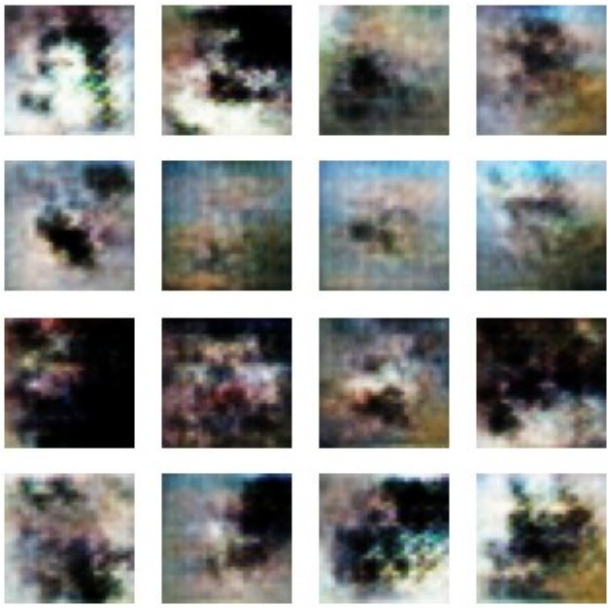


```
Epoch 11/100 - Generator Loss: 0.8928, Discriminator Loss: 1.6335 -
Time Taken: 155.94 sec

<Figure size 640x480 with 0 Axes>
```




```
Epoch 12/100 - Generator Loss: 1.2045, Discriminator Loss: 1.0142 -
Time Taken: 156.27 sec

<Figure size 640x480 with 0 Axes>
```

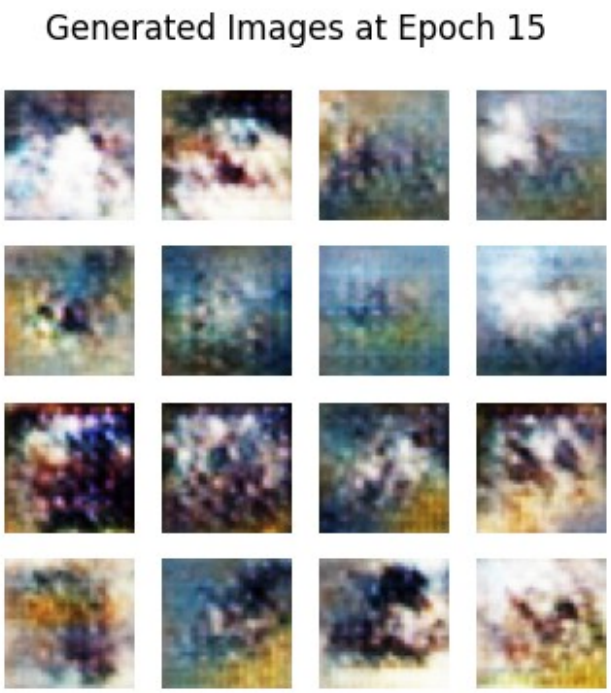
Generated Images at Epoch 13



```
Epoch 13/100 - Generator Loss: 1.0434, Discriminator Loss: 1.0453 -
Time Taken: 157.41 sec

<Figure size 640x480 with 0 Axes>
```

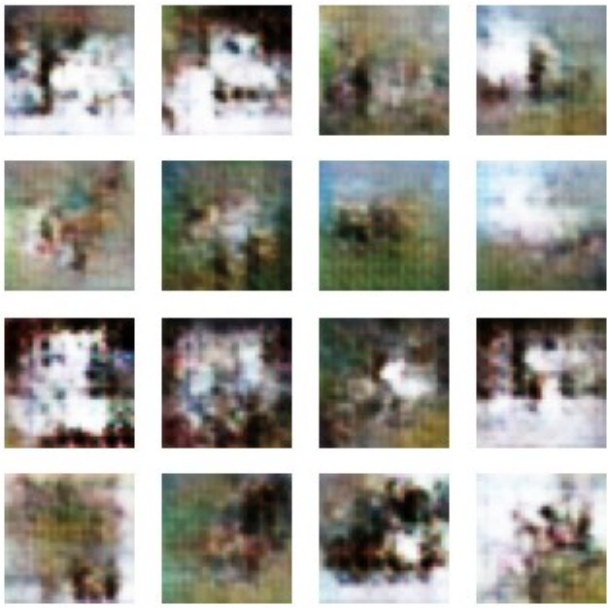
Generated Images at Epoch 14

```
Epoch 14/100 - Generator Loss: 0.9640, Discriminator Loss: 1.0896 -
Time Taken: 155.61 sec

<Figure size 640x480 with 0 Axes>
```



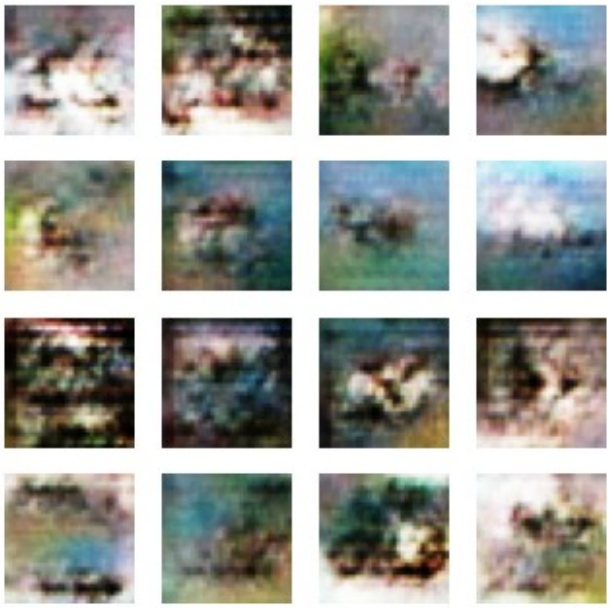

```
Epoch 15/100 - Generator Loss: 0.9160, Discriminator Loss: 1.2906 -
Time Taken: 160.00 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 16

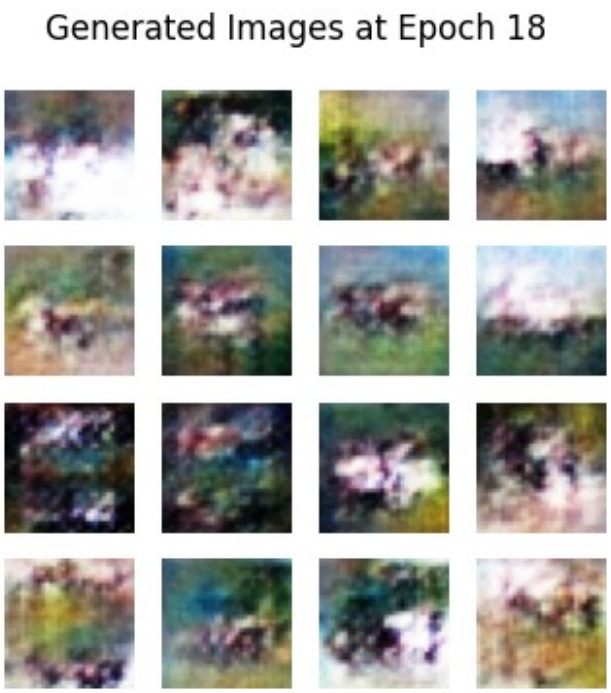


```
Epoch 16/100 - Generator Loss: 0.8248, Discriminator Loss: 1.6522 -
Time Taken: 156.40 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 17



```
Epoch 17/100 - Generator Loss: 1.2123, Discriminator Loss: 0.8915 -
Time Taken: 156.01 sec

<Figure size 640x480 with 0 Axes>
```



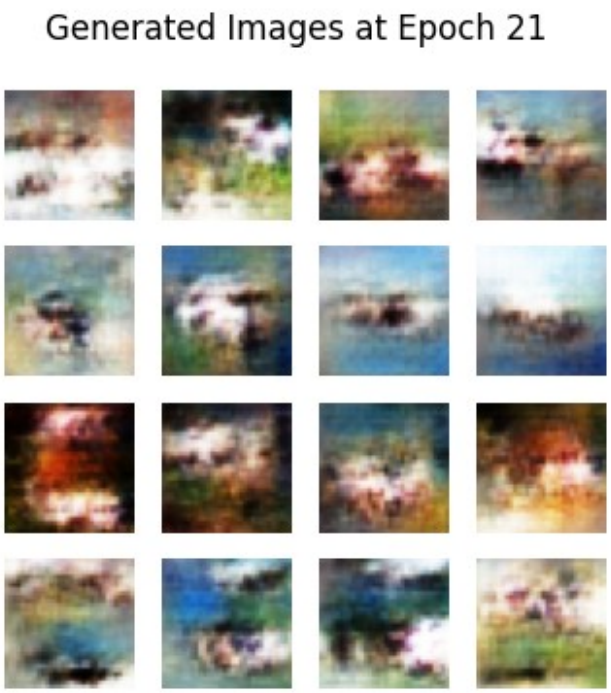

```
Epoch 18/100 - Generator Loss: 1.0547, Discriminator Loss: 1.1490 -
Time Taken: 156.06 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 19

```
Epoch 19/100 - Generator Loss: 0.9116, Discriminator Loss: 1.3088 -
Time Taken: 158.26 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 20

```
Epoch 20/100 - Generator Loss: 1.1773, Discriminator Loss: 1.0139 -
Time Taken: 160.95 sec

<Figure size 640x480 with 0 Axes>
```

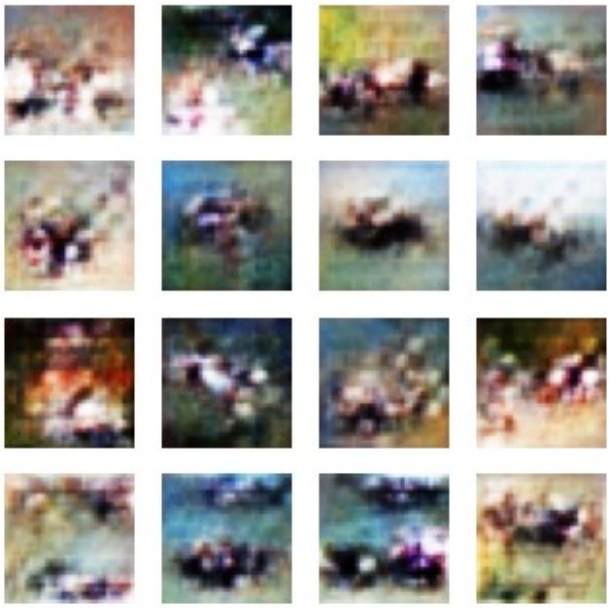



```
Epoch 21/100 - Generator Loss: 0.9831, Discriminator Loss: 1.0983 -
Time Taken: 156.52 sec

<Figure size 640x480 with 0 Axes>
```

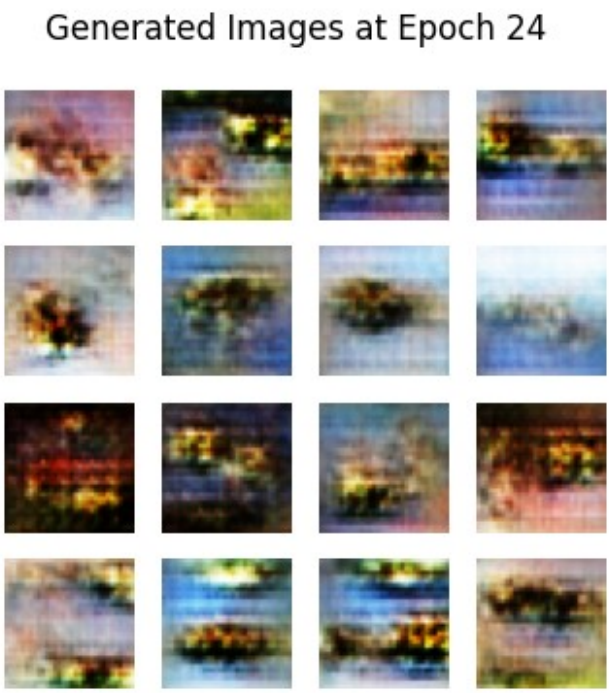
Generated Images at Epoch 22

```
Epoch 22/100 - Generator Loss: 1.0132, Discriminator Loss: 0.9665 -
Time Taken: 156.92 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 23



```
Epoch 23/100 - Generator Loss: 1.1542, Discriminator Loss: 1.1903 -
Time Taken: 156.20 sec

<Figure size 640x480 with 0 Axes>
```



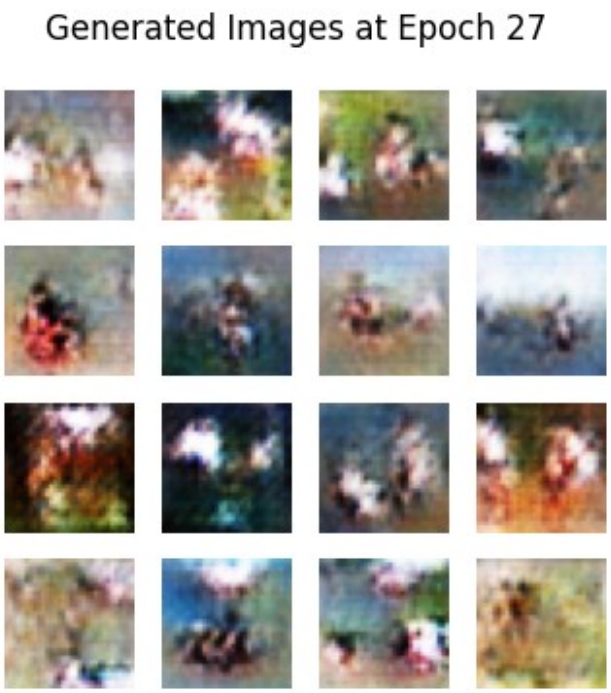

```
Epoch 24/100 - Generator Loss: 1.1038, Discriminator Loss: 1.1550 -
Time Taken: 157.13 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 25

```
Epoch 25/100 - Generator Loss: 1.0746, Discriminator Loss: 0.9275 -
Time Taken: 156.16 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 26

```
Epoch 26/100 - Generator Loss: 0.9935, Discriminator Loss: 1.1247 -
Time Taken: 156.03 sec

<Figure size 640x480 with 0 Axes>
```

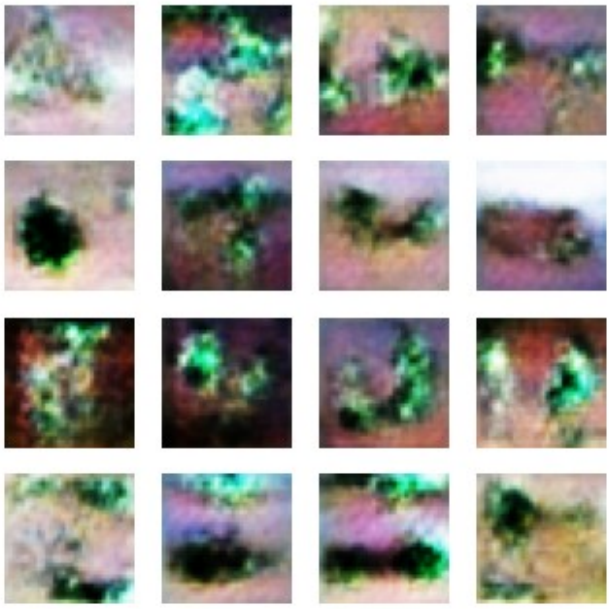



```
Epoch 27/100 - Generator Loss: 1.0260, Discriminator Loss: 1.1715 -
Time Taken: 156.72 sec

<Figure size 640x480 with 0 Axes>
```

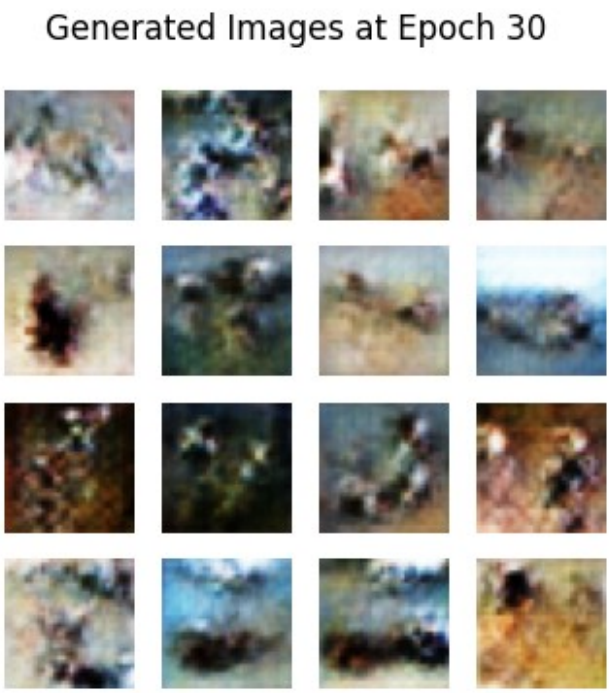
Generated Images at Epoch 28

```
Epoch 28/100 - Generator Loss: 1.1032, Discriminator Loss: 1.2488 -
Time Taken: 156.56 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 29



```
Epoch 29/100 - Generator Loss: 1.1730, Discriminator Loss: 0.7714 -
Time Taken: 156.32 sec

<Figure size 640x480 with 0 Axes>
```

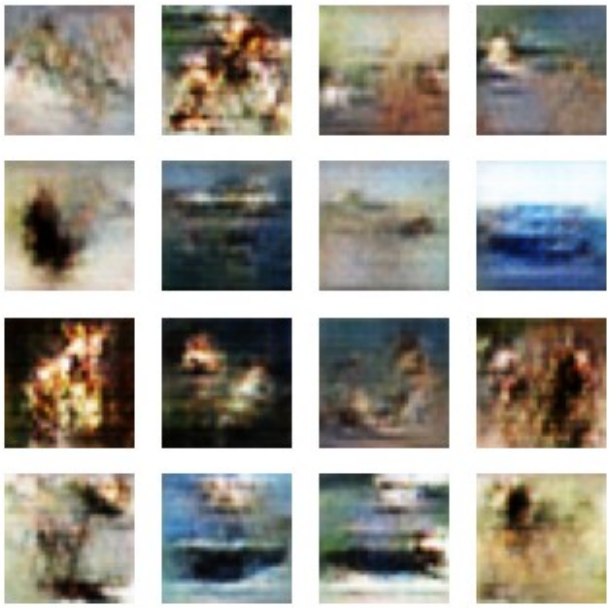



```
Epoch 30/100 - Generator Loss: 1.0729, Discriminator Loss: 1.3286 -
Time Taken: 157.97 sec

<Figure size 640x480 with 0 Axes>
```

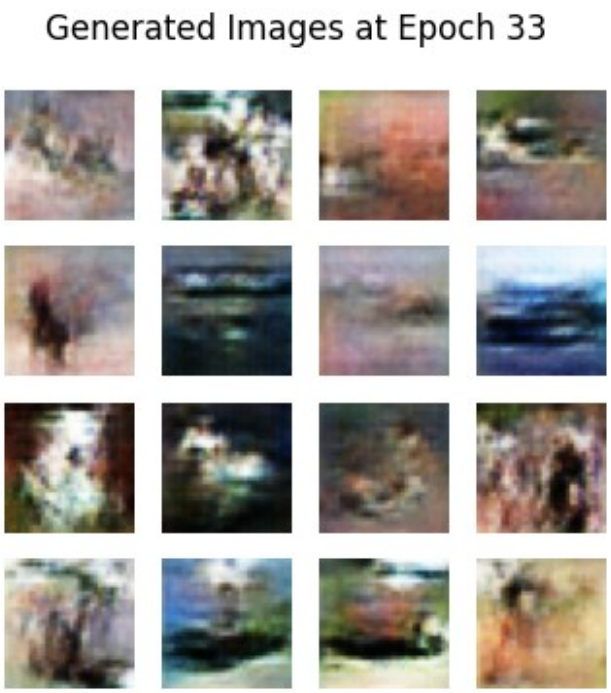
Generated Images at Epoch 31

```
Epoch 31/100 - Generator Loss: 1.3947, Discriminator Loss: 1.1169 -
Time Taken: 156.96 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 32

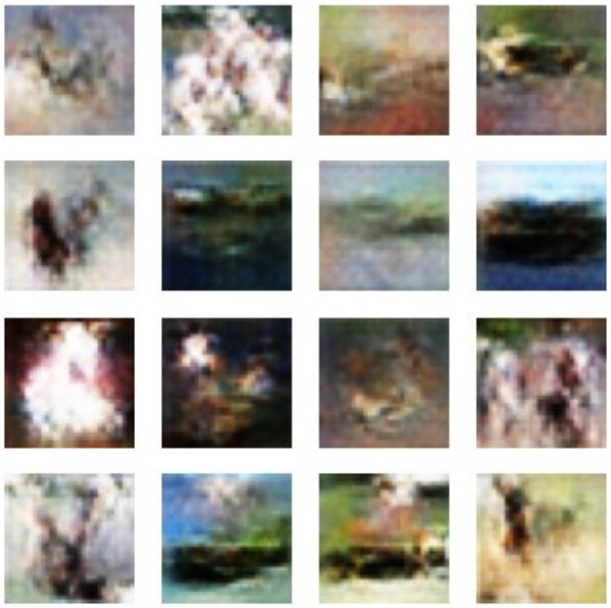


```
Epoch 32/100 - Generator Loss: 1.0527, Discriminator Loss: 1.3176 -
Time Taken: 158.68 sec

<Figure size 640x480 with 0 Axes>
```



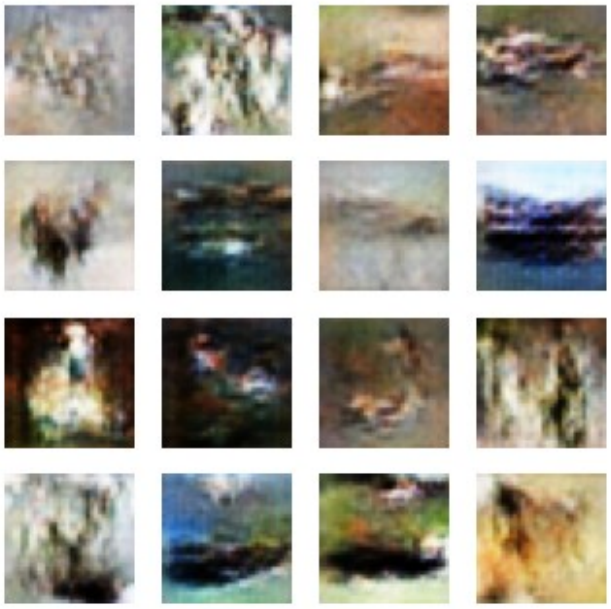

```
Epoch 33/100 - Generator Loss: 1.5937, Discriminator Loss: 0.7611 -
Time Taken: 162.52 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 34

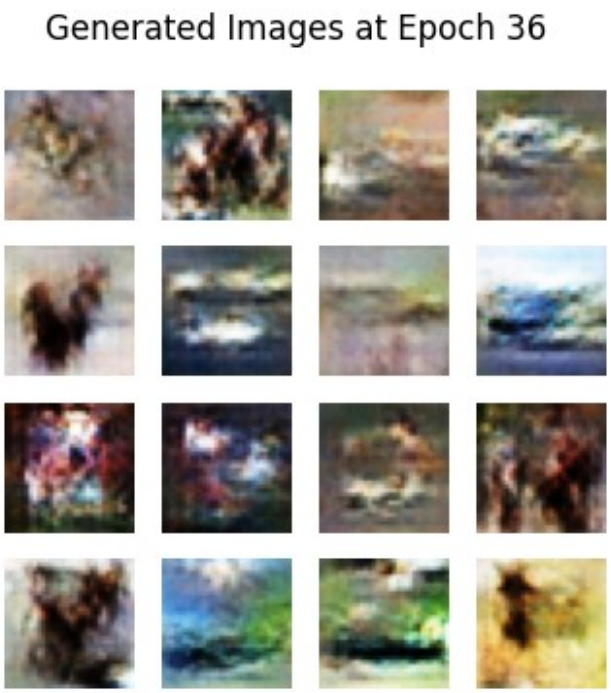


```
Epoch 34/100 - Generator Loss: 1.2580, Discriminator Loss: 0.9335 -
Time Taken: 159.49 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 35

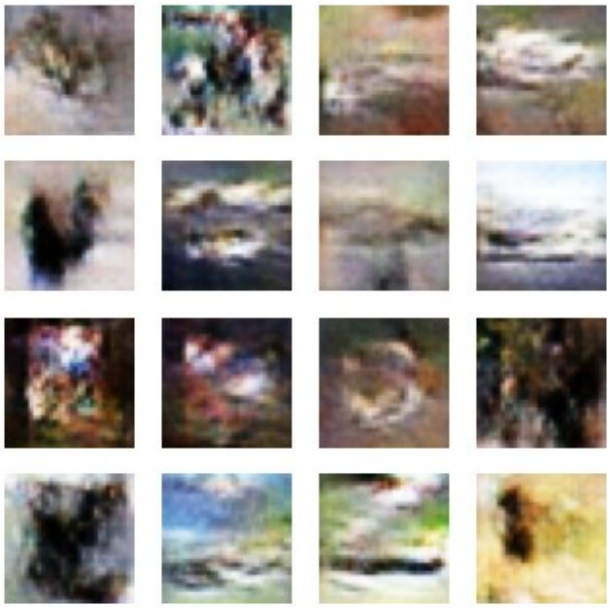


```
Epoch 35/100 - Generator Loss: 1.1185, Discriminator Loss: 1.3051 -
Time Taken: 157.73 sec

<Figure size 640x480 with 0 Axes>
```



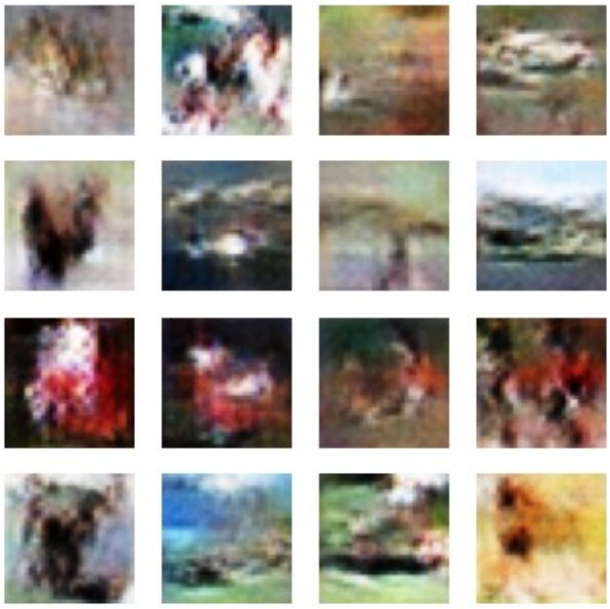

```
Epoch 36/100 - Generator Loss: 1.2999, Discriminator Loss: 0.9704 -
Time Taken: 159.24 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 37

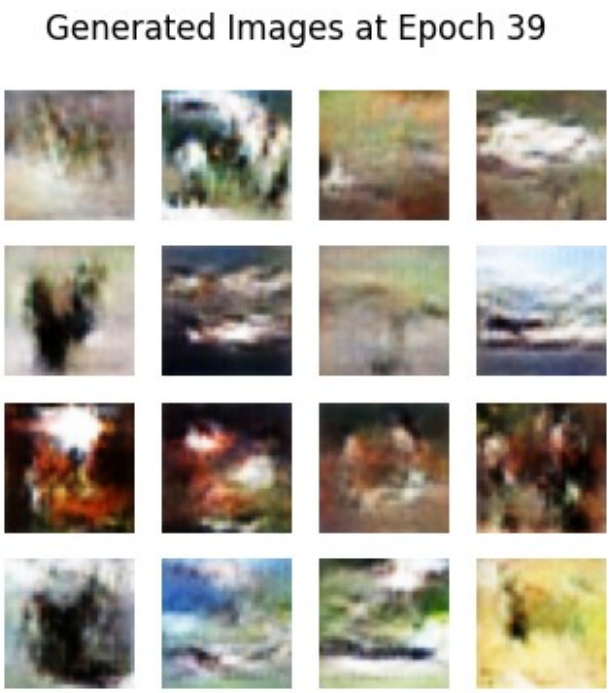


```
Epoch 37/100 - Generator Loss: 1.2421, Discriminator Loss: 0.9770 -
Time Taken: 155.95 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 38

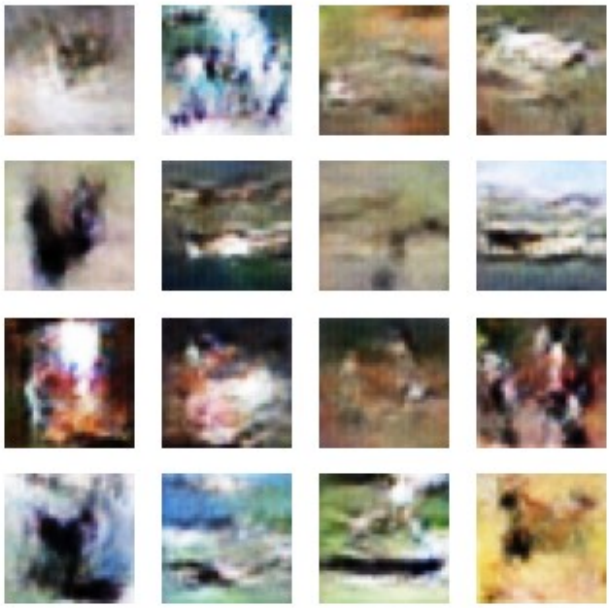


```
Epoch 38/100 - Generator Loss: 1.0985, Discriminator Loss: 1.3586 -
Time Taken: 160.45 sec

<Figure size 640x480 with 0 Axes>
```



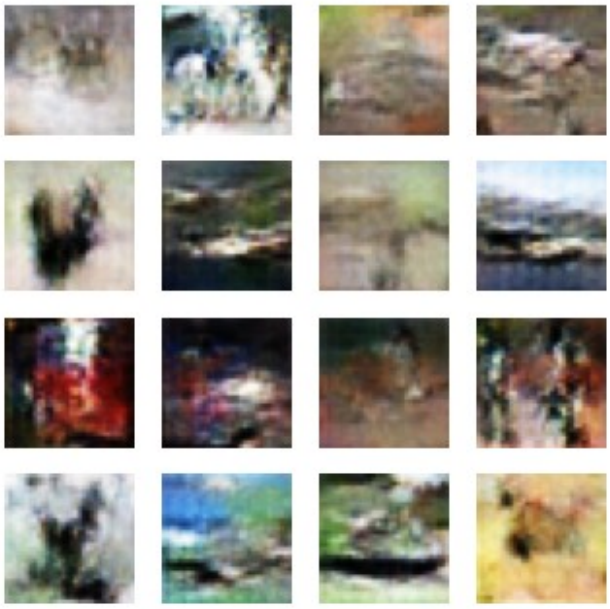

```
Epoch 39/100 - Generator Loss: 1.4627, Discriminator Loss: 0.8453 -
Time Taken: 156.66 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 40

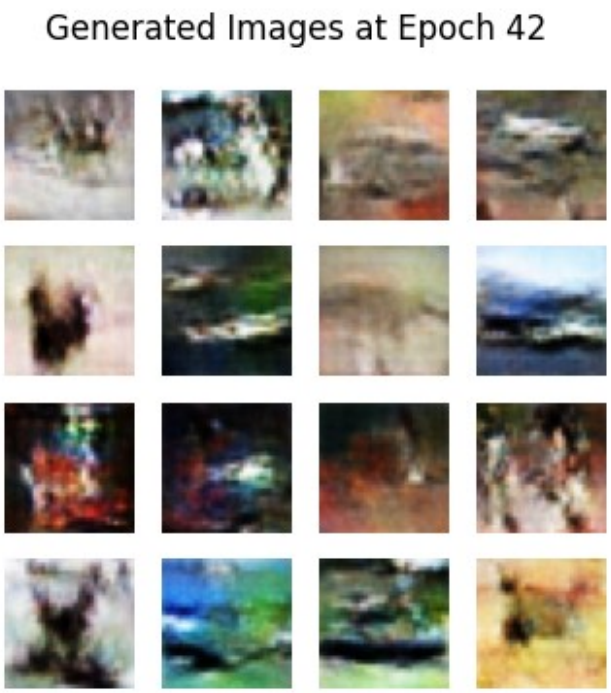


```
Epoch 40/100 - Generator Loss: 1.2762, Discriminator Loss: 1.1688 -
Time Taken: 156.91 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 41

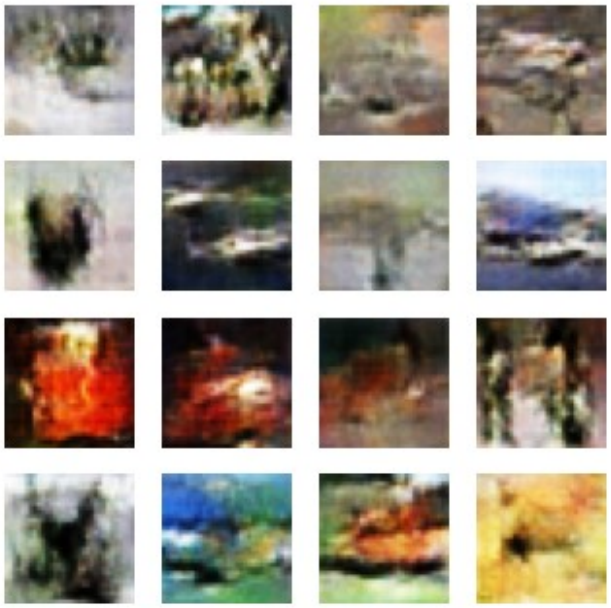


```
Epoch 41/100 - Generator Loss: 1.1450, Discriminator Loss: 1.1354 -
Time Taken: 159.32 sec

<Figure size 640x480 with 0 Axes>
```



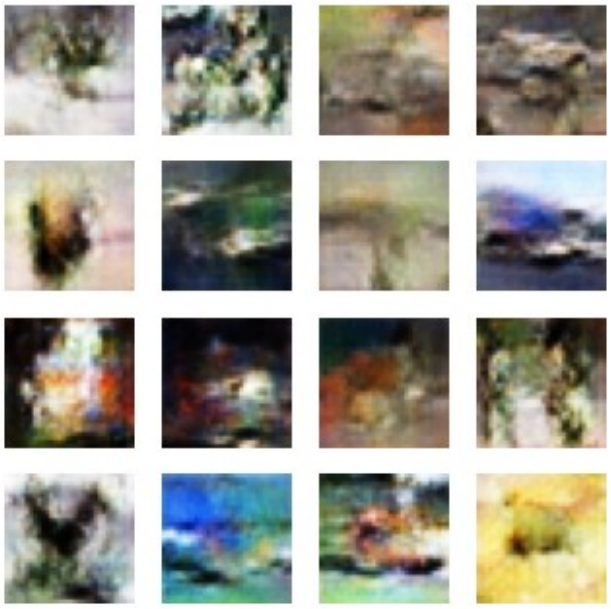

```
Epoch 42/100 - Generator Loss: 1.1264, Discriminator Loss: 1.2262 -
Time Taken: 157.60 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 43

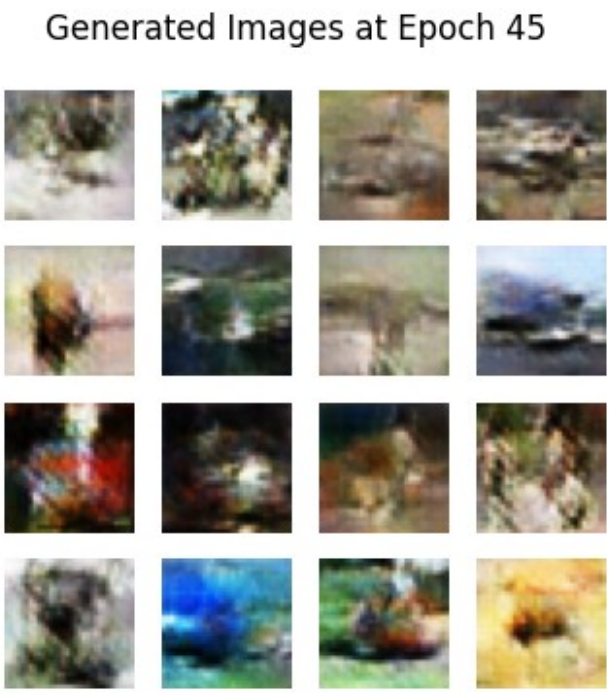


```
Epoch 43/100 - Generator Loss: 1.2602, Discriminator Loss: 1.2943 -
Time Taken: 156.18 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 44

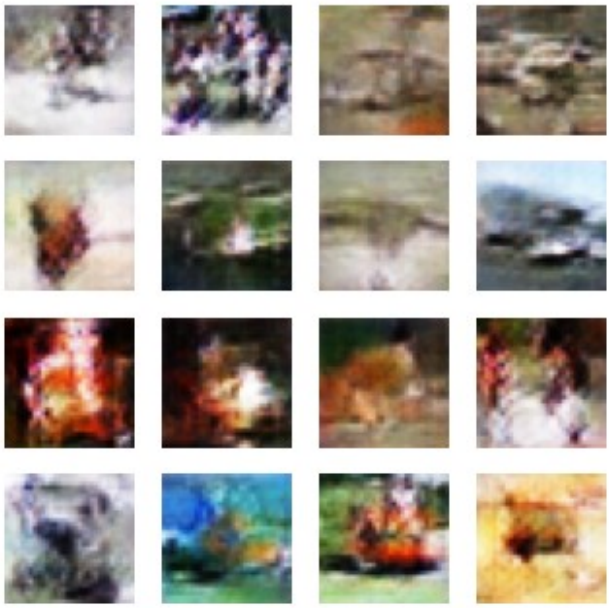


```
Epoch 44/100 - Generator Loss: 0.8526, Discriminator Loss: 1.1841 -
Time Taken: 156.62 sec

<Figure size 640x480 with 0 Axes>
```



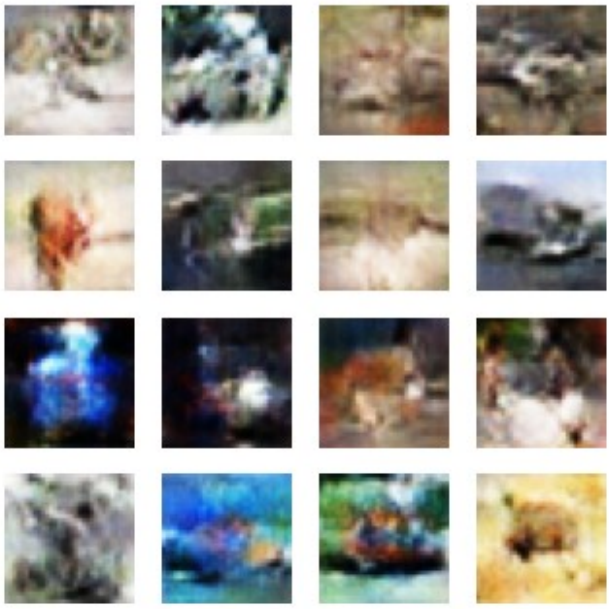

```
Epoch 45/100 - Generator Loss: 1.1130, Discriminator Loss: 1.0342 -
Time Taken: 156.47 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 46

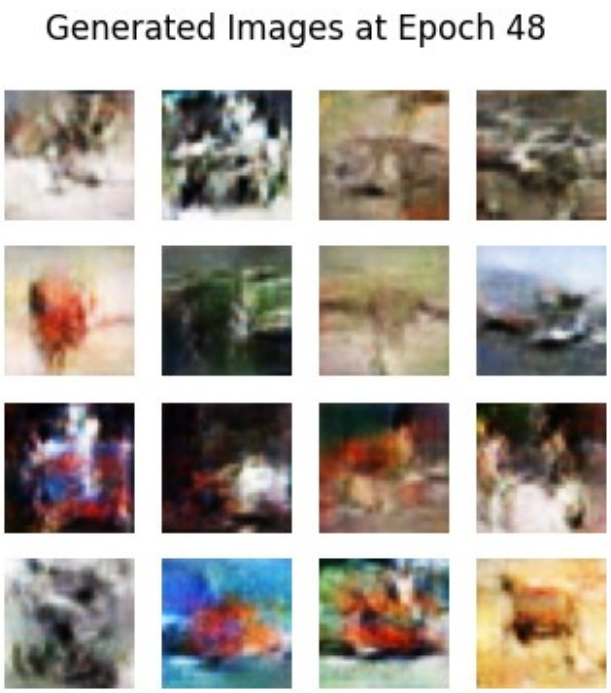


```
Epoch 46/100 - Generator Loss: 1.0734, Discriminator Loss: 1.1260 -
Time Taken: 156.39 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 47

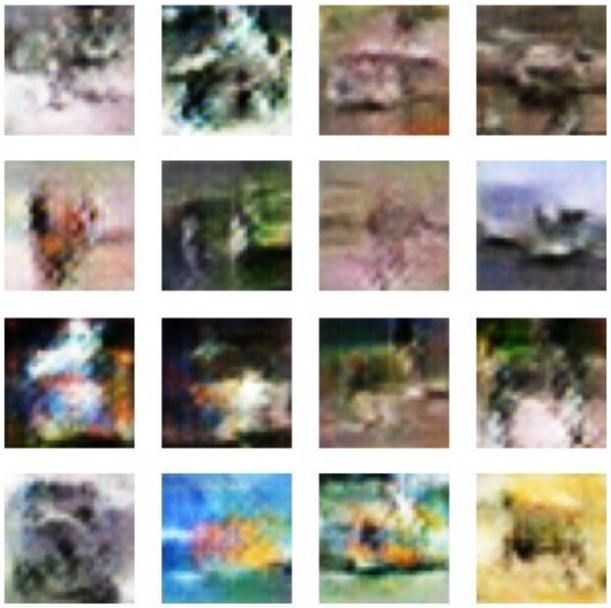


```
Epoch 47/100 - Generator Loss: 0.9555, Discriminator Loss: 1.3291 -
Time Taken: 156.82 sec

<Figure size 640x480 with 0 Axes>
```



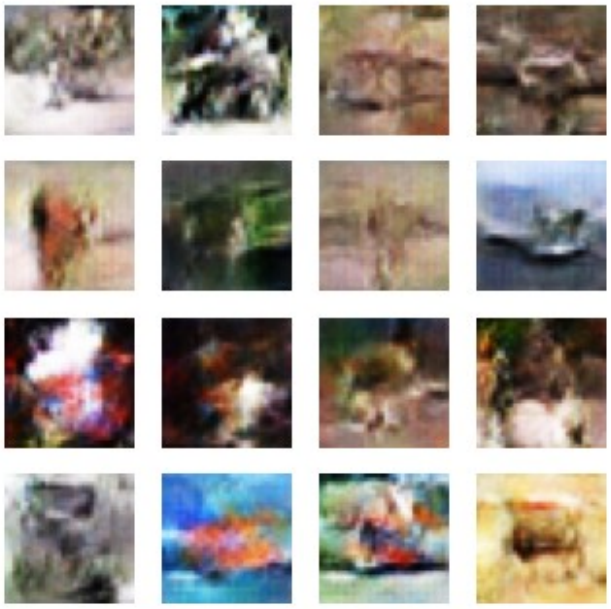

```
Epoch 48/100 - Generator Loss: 1.1265, Discriminator Loss: 1.4634 -
Time Taken: 156.17 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 49

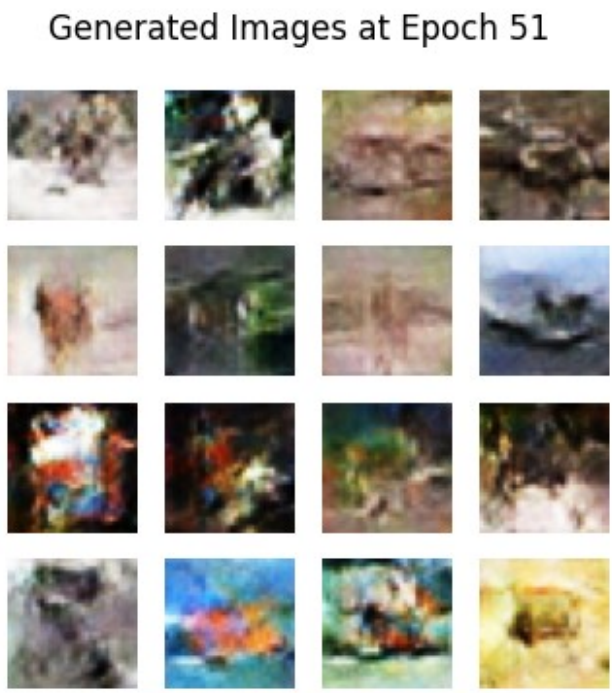


```
Epoch 49/100 - Generator Loss: 1.2326, Discriminator Loss: 1.0481 -
Time Taken: 157.89 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 50

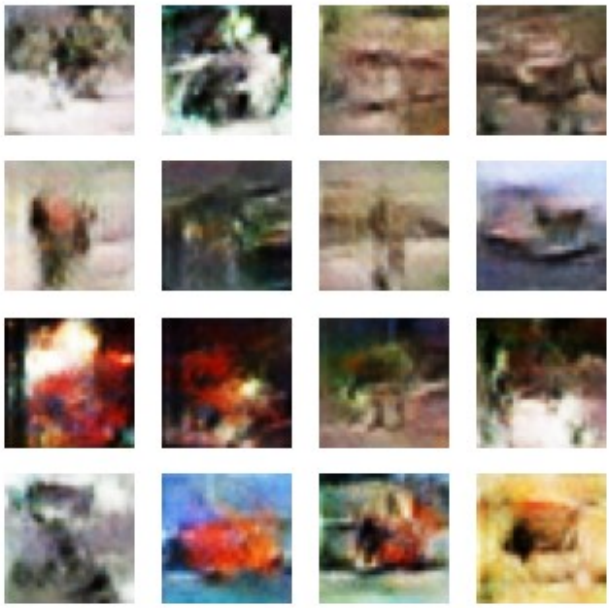


```
Epoch 50/100 - Generator Loss: 0.8791, Discriminator Loss: 1.3052 -
Time Taken: 156.59 sec

<Figure size 640x480 with 0 Axes>
```



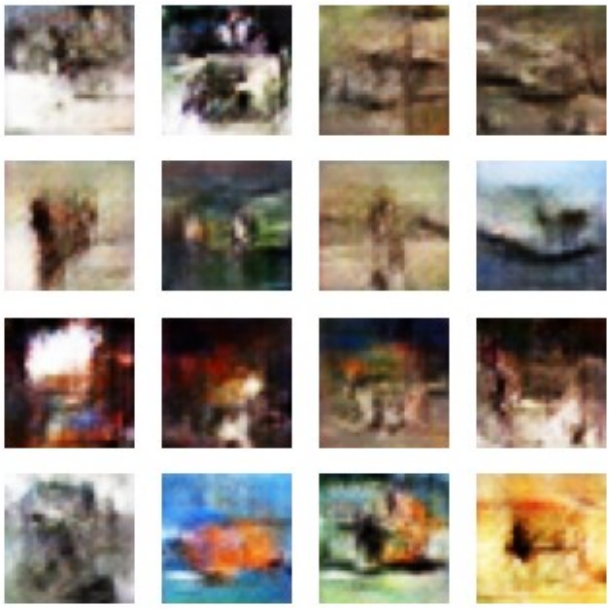

```
Epoch 51/100 - Generator Loss: 1.0660, Discriminator Loss: 0.9225 -
Time Taken: 155.79 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 52

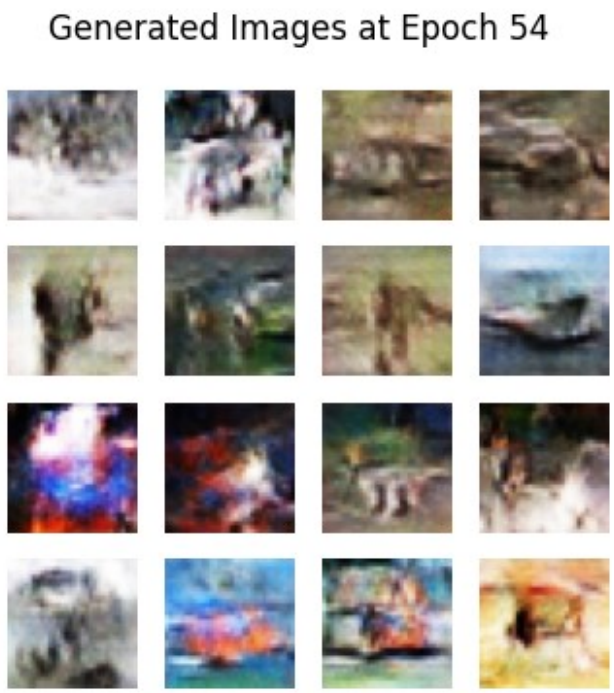


```
Epoch 52/100 - Generator Loss: 1.2222, Discriminator Loss: 1.2645 -
Time Taken: 155.69 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 53

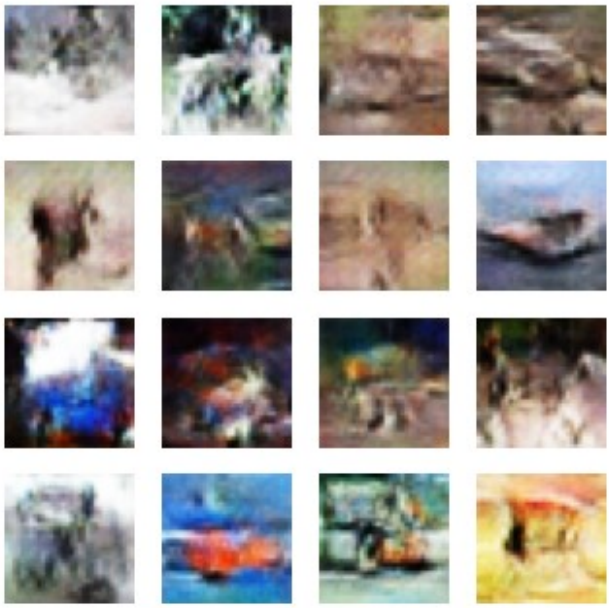


```
Epoch 53/100 - Generator Loss: 1.4689, Discriminator Loss: 1.1544 -
Time Taken: 157.59 sec

<Figure size 640x480 with 0 Axes>
```



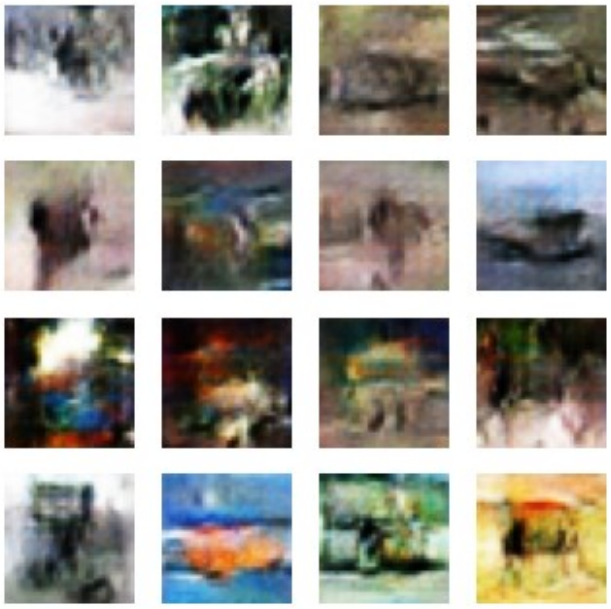

```
Epoch 54/100 - Generator Loss: 0.9999, Discriminator Loss: 1.1987 -
Time Taken: 156.31 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 55

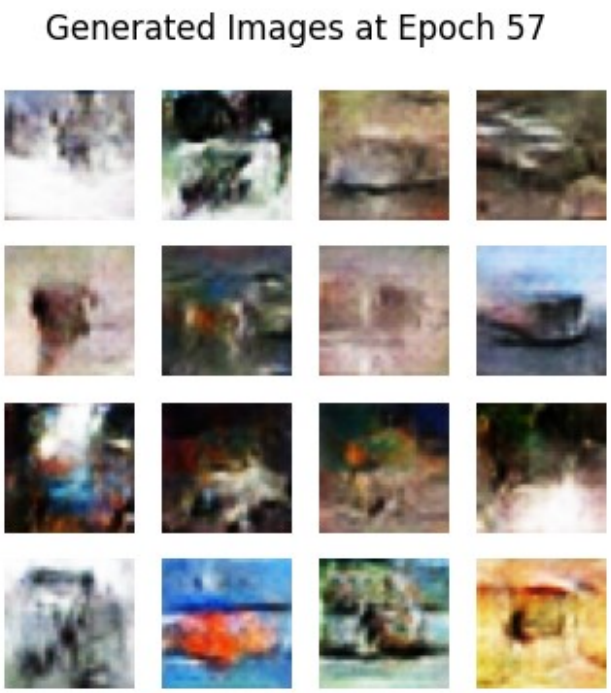


```
Epoch 55/100 - Generator Loss: 1.1720, Discriminator Loss: 1.1516 -
Time Taken: 156.93 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 56

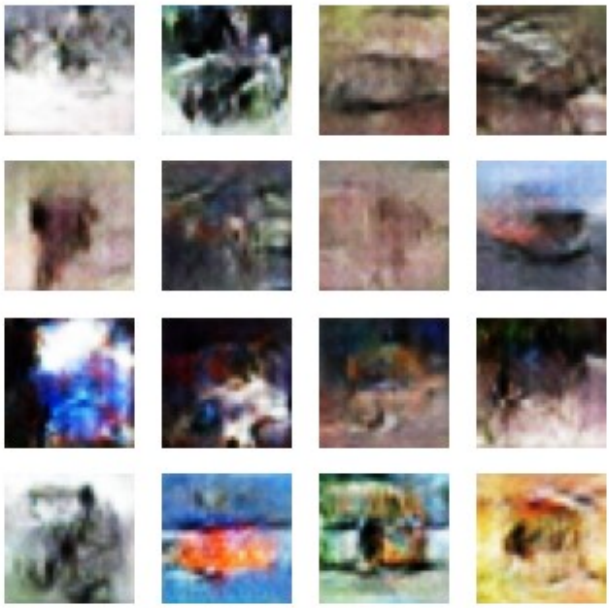


```
Epoch 56/100 - Generator Loss: 1.0397, Discriminator Loss: 1.3021 -
Time Taken: 155.96 sec

<Figure size 640x480 with 0 Axes>
```



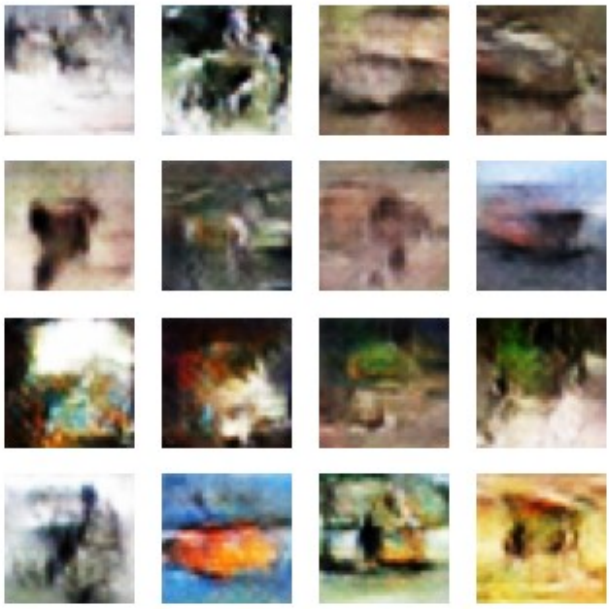

```
Epoch 57/100 - Generator Loss: 1.1892, Discriminator Loss: 0.9922 -
Time Taken: 156.39 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 58

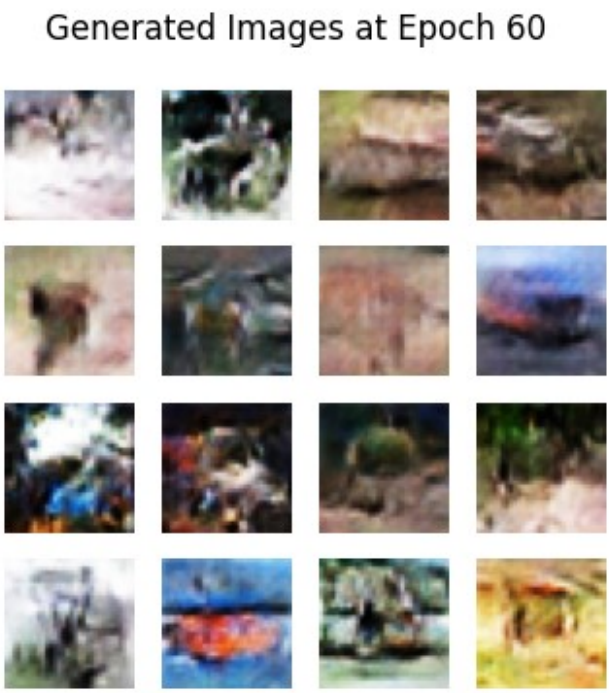


```
Epoch 58/100 - Generator Loss: 1.1008, Discriminator Loss: 1.1881 -
Time Taken: 155.72 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 59

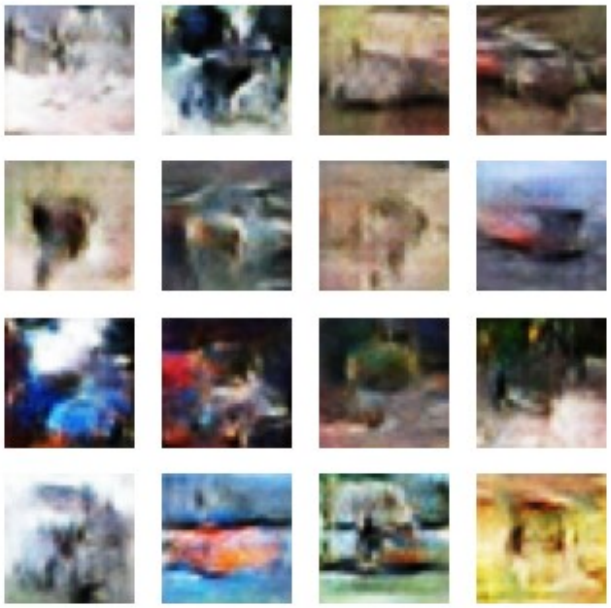


```
Epoch 59/100 - Generator Loss: 0.9843, Discriminator Loss: 0.9189 -
Time Taken: 156.44 sec

<Figure size 640x480 with 0 Axes>
```



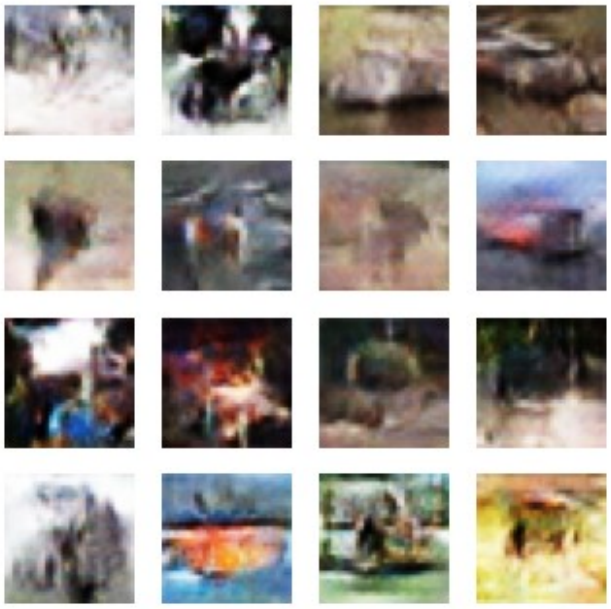

```
Epoch 60/100 - Generator Loss: 1.1277, Discriminator Loss: 0.8943 -
Time Taken: 157.23 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 61

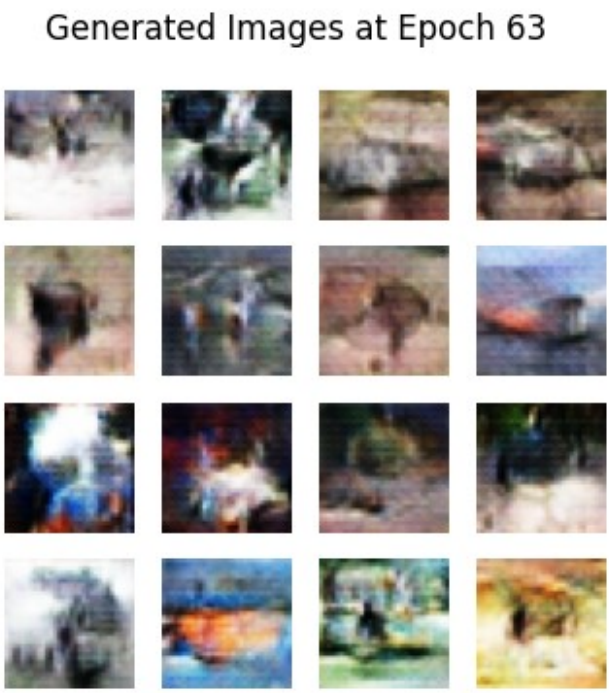


```
Epoch 61/100 - Generator Loss: 1.2222, Discriminator Loss: 1.1953 -
Time Taken: 157.34 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 62

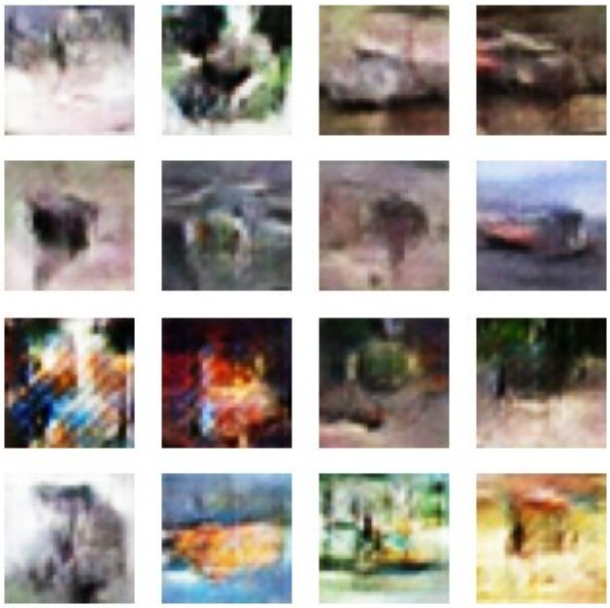


```
Epoch 62/100 - Generator Loss: 1.1388, Discriminator Loss: 1.2270 -
Time Taken: 158.14 sec

<Figure size 640x480 with 0 Axes>
```



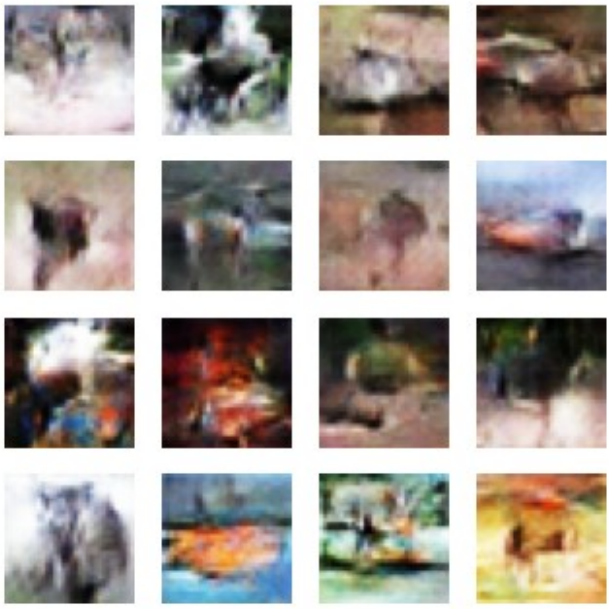

```
Epoch 63/100 - Generator Loss: 1.3563, Discriminator Loss: 0.8103 -
Time Taken: 161.55 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 64

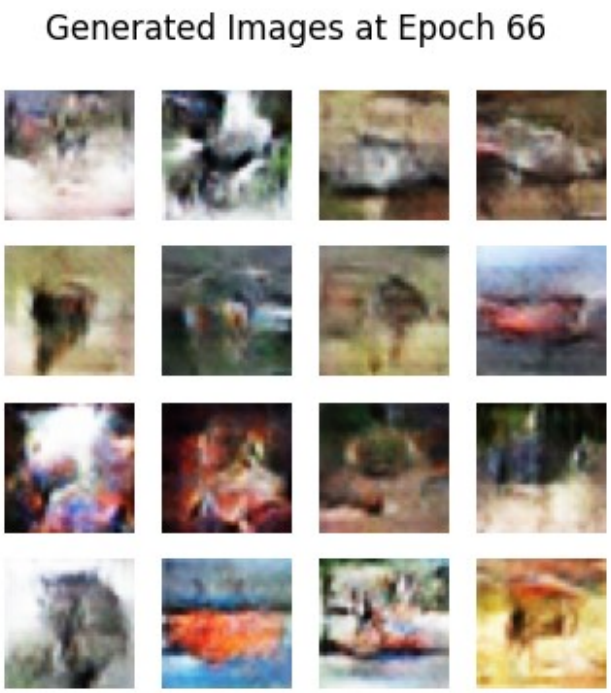


```
Epoch 64/100 - Generator Loss: 1.1755, Discriminator Loss: 1.2944 -
Time Taken: 162.24 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 65

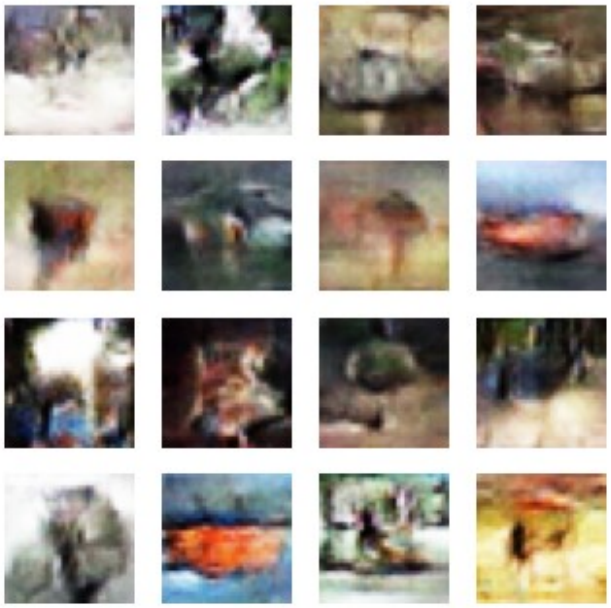


```
Epoch 65/100 - Generator Loss: 1.0022, Discriminator Loss: 1.1964 -
Time Taken: 163.97 sec

<Figure size 640x480 with 0 Axes>
```



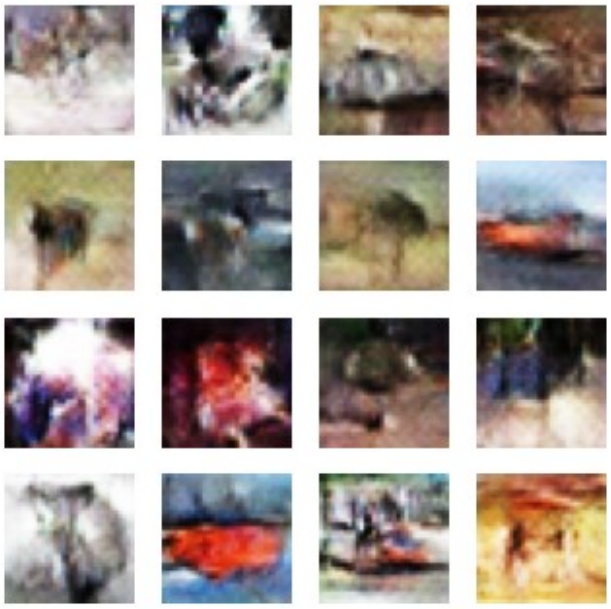

```
Epoch 66/100 - Generator Loss: 1.2827, Discriminator Loss: 1.5088 -
Time Taken: 156.49 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 67

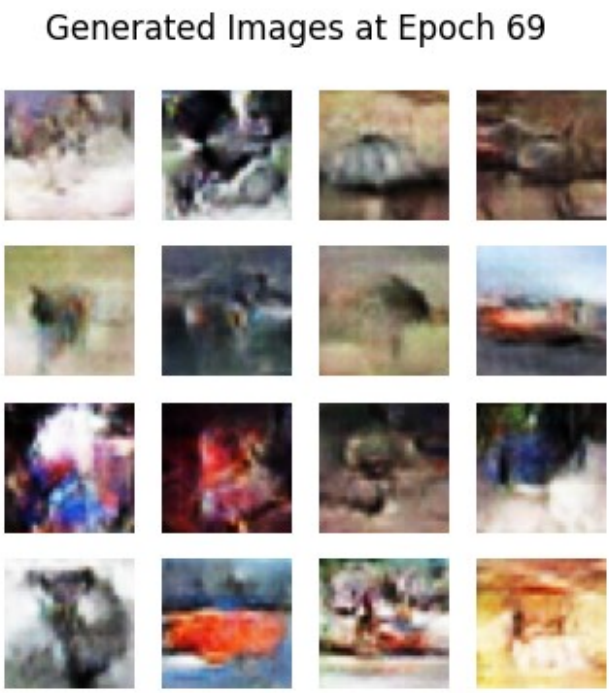


```
Epoch 67/100 - Generator Loss: 1.4232, Discriminator Loss: 0.8453 -
Time Taken: 156.14 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 68

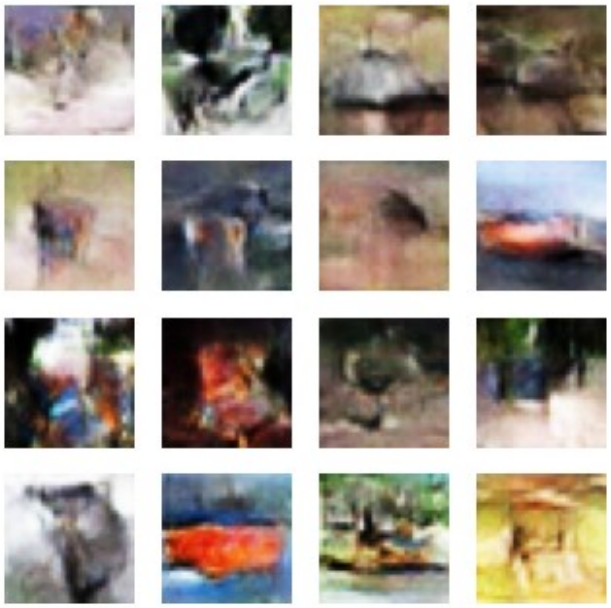


```
Epoch 68/100 - Generator Loss: 1.1634, Discriminator Loss: 1.0500 -
Time Taken: 156.45 sec

<Figure size 640x480 with 0 Axes>
```



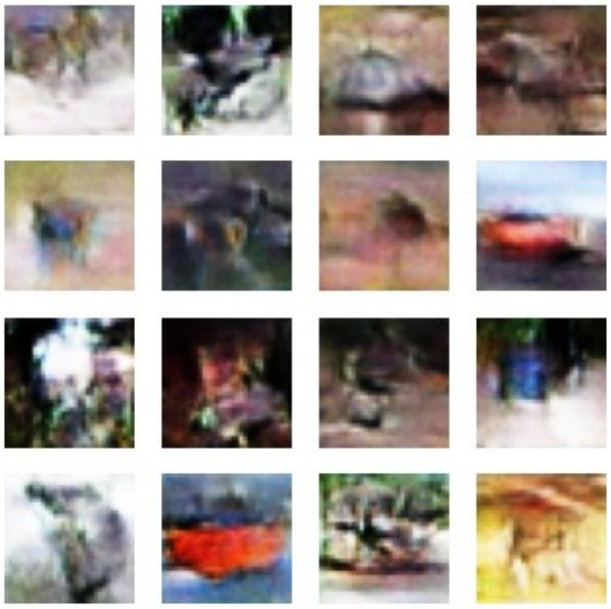

```
Epoch 69/100 - Generator Loss: 1.0675, Discriminator Loss: 1.0085 -
Time Taken: 156.18 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 70

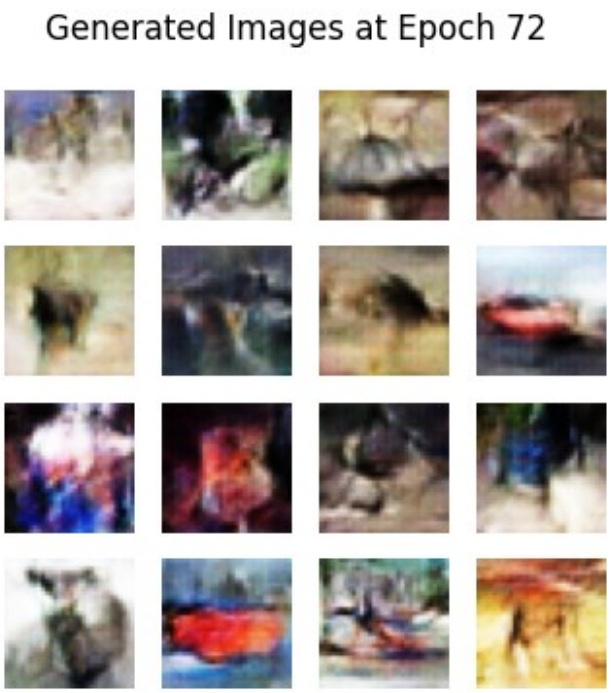


```
Epoch 70/100 - Generator Loss: 1.1919, Discriminator Loss: 0.9675 -
Time Taken: 156.95 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 71

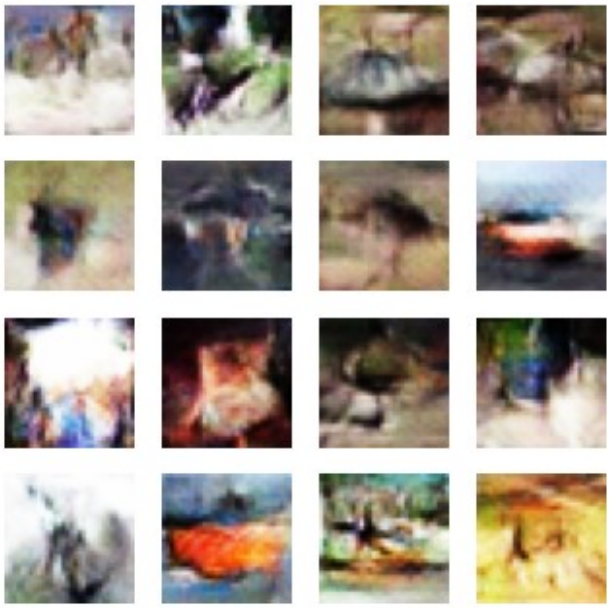


```
Epoch 71/100 - Generator Loss: 1.1848, Discriminator Loss: 1.5320 - Time Taken: 156.00 sec

<Figure size 640x480 with 0 Axes>
```



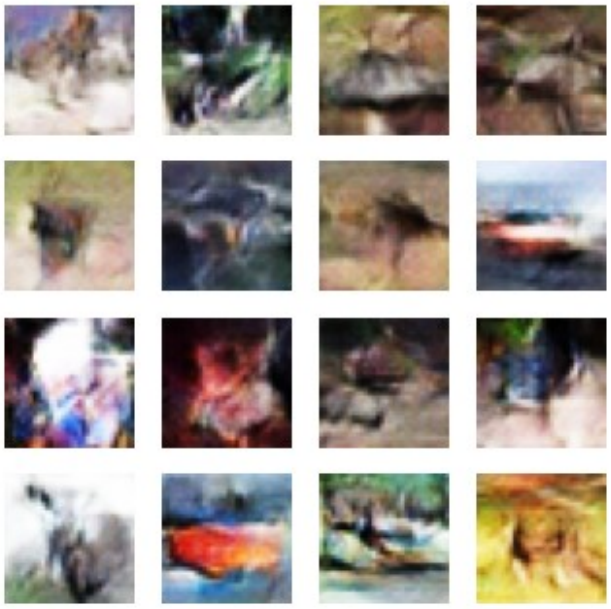

```
Epoch 72/100 - Generator Loss: 1.3209, Discriminator Loss: 0.9803 - Time Taken: 155.16 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 73

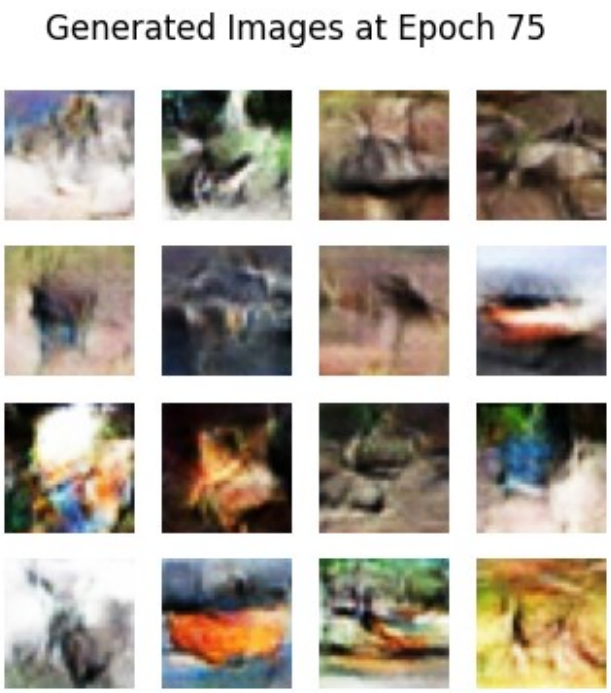


```
Epoch 73/100 - Generator Loss: 0.8987, Discriminator Loss: 1.3290 -
Time Taken: 156.59 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 74

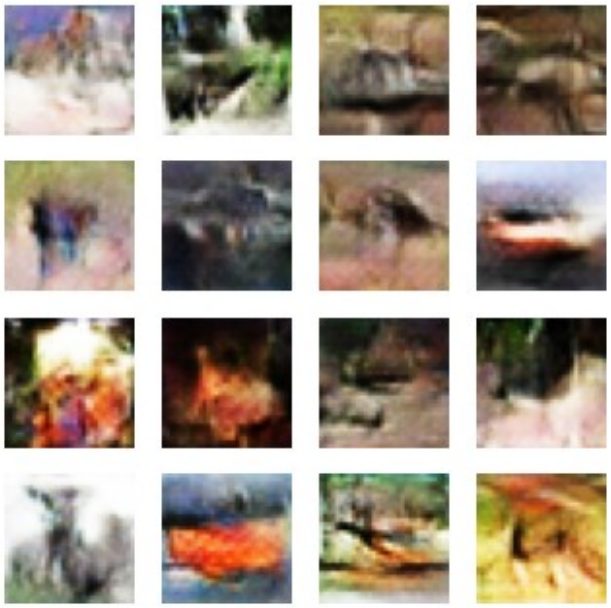


```
Epoch 74/100 - Generator Loss: 1.3787, Discriminator Loss: 0.9477 - Time Taken: 155.80 sec

<Figure size 640x480 with 0 Axes>
```



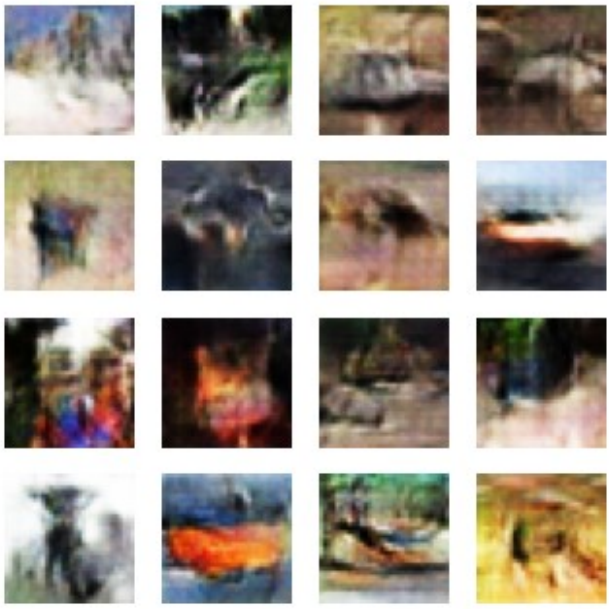

```
Epoch 75/100 - Generator Loss: 1.0859, Discriminator Loss: 1.0391 - Time Taken: 155.40 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 76

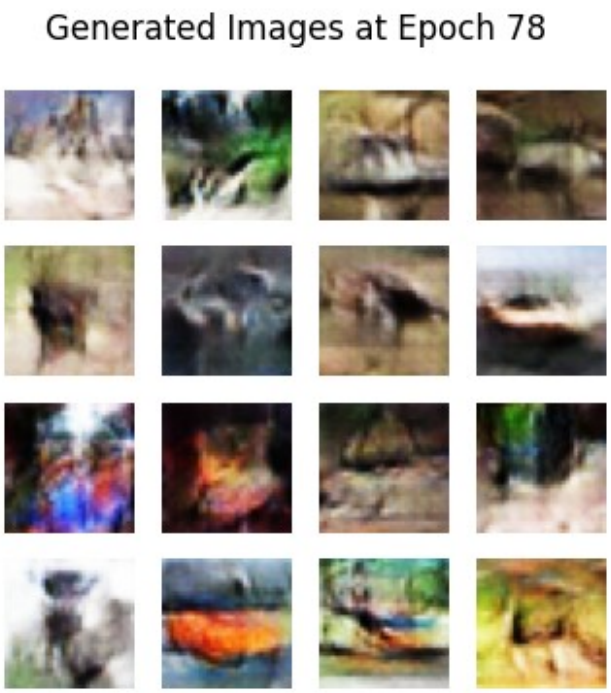


```
Epoch 76/100 - Generator Loss: 1.2058, Discriminator Loss: 1.1969 -
Time Taken: 157.58 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 77

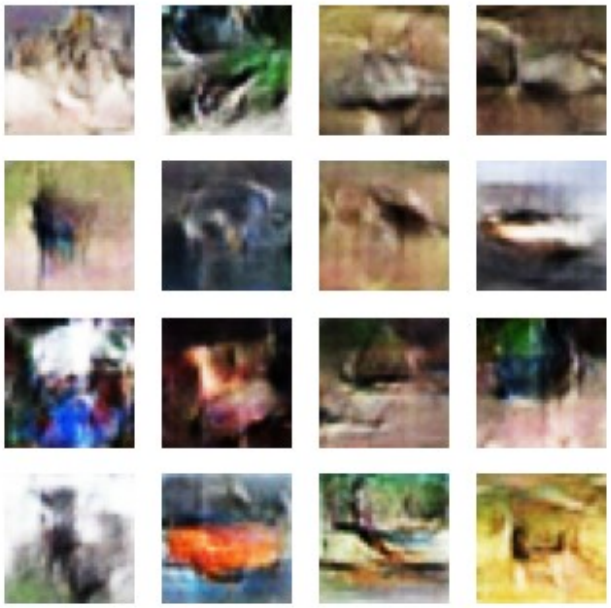


```
Epoch 77/100 - Generator Loss: 1.4552, Discriminator Loss: 1.1564 -
Time Taken: 160.29 sec

<Figure size 640x480 with 0 Axes>
```



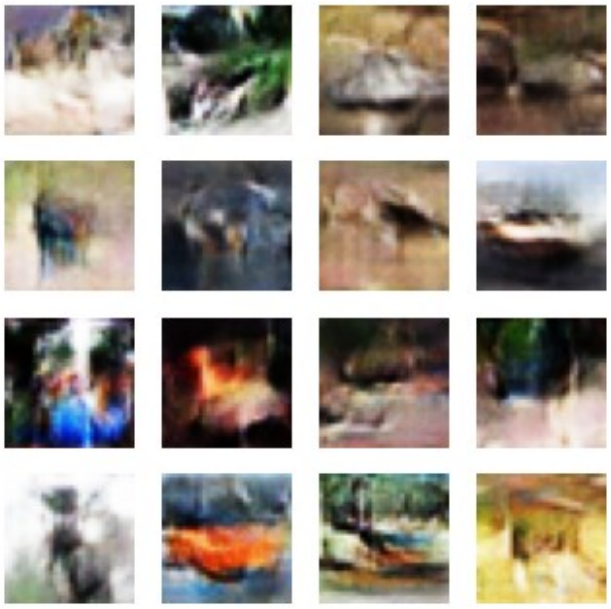

```
Epoch 78/100 - Generator Loss: 1.4965, Discriminator Loss: 0.7879 -
Time Taken: 159.86 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 79

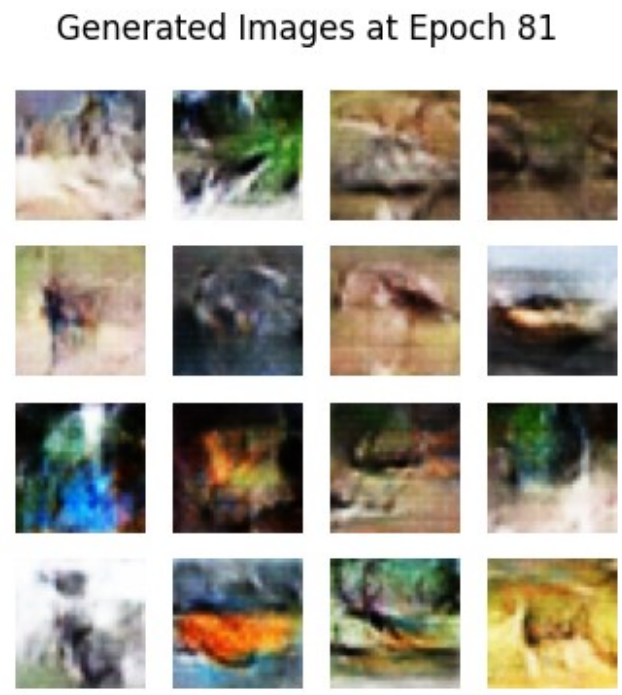


```
Epoch 79/100 - Generator Loss: 1.4413, Discriminator Loss: 1.0765 - Time Taken: 156.42 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 80

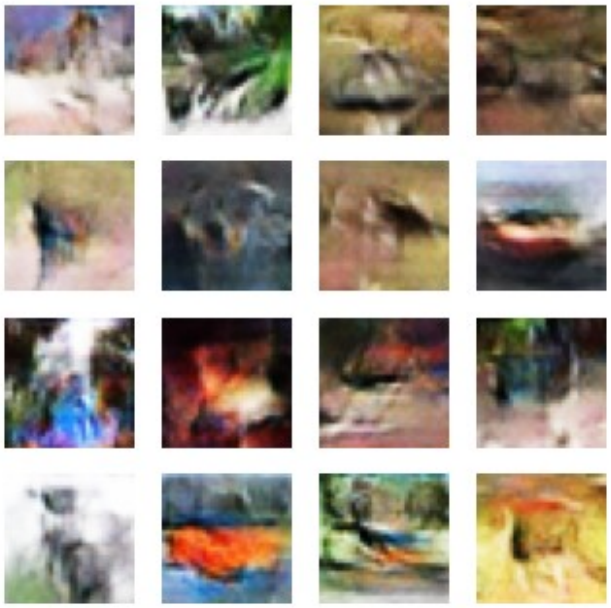


```
Epoch 80/100 - Generator Loss: 0.8938, Discriminator Loss: 1.4187 -
Time Taken: 157.91 sec

<Figure size 640x480 with 0 Axes>
```



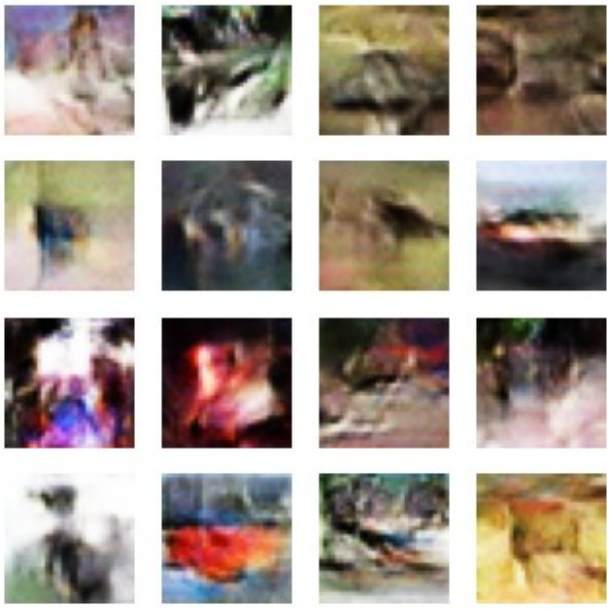

```
Epoch 81/100 - Generator Loss: 1.0738, Discriminator Loss: 1.2642 -
Time Taken: 157.31 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 82

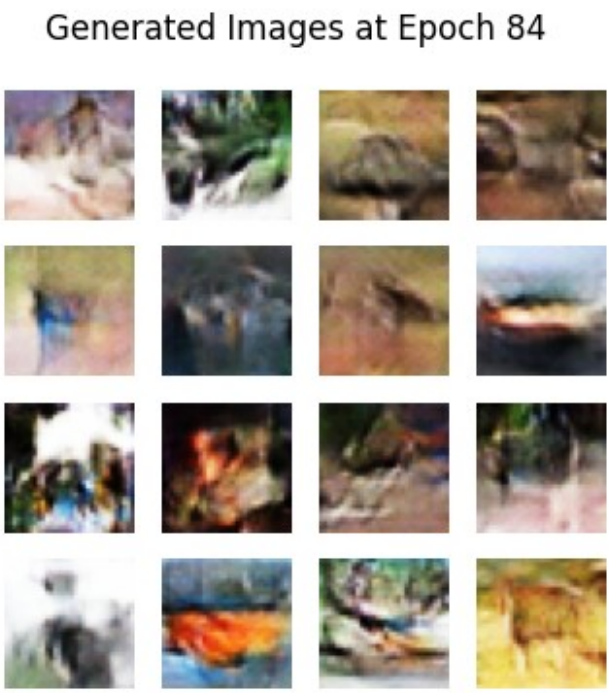


```
Epoch 82/100 - Generator Loss: 1.0687, Discriminator Loss: 1.2624 -
Time Taken: 157.98 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 83

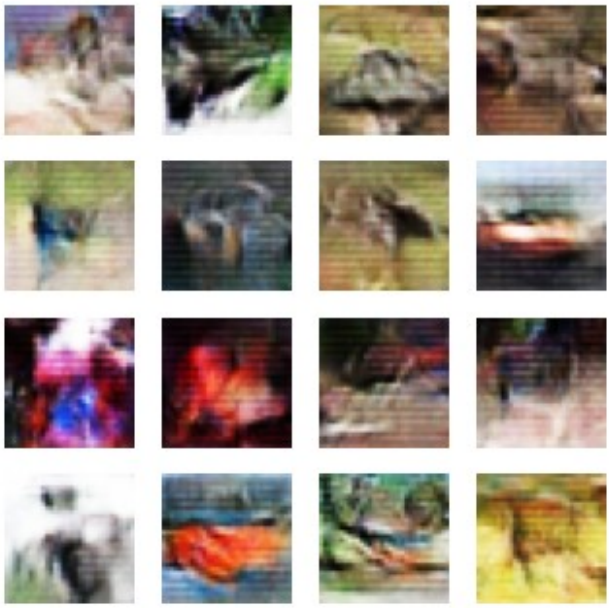


```
Epoch 83/100 - Generator Loss: 1.1962, Discriminator Loss: 1.1078 -
Time Taken: 156.44 sec

<Figure size 640x480 with 0 Axes>
```



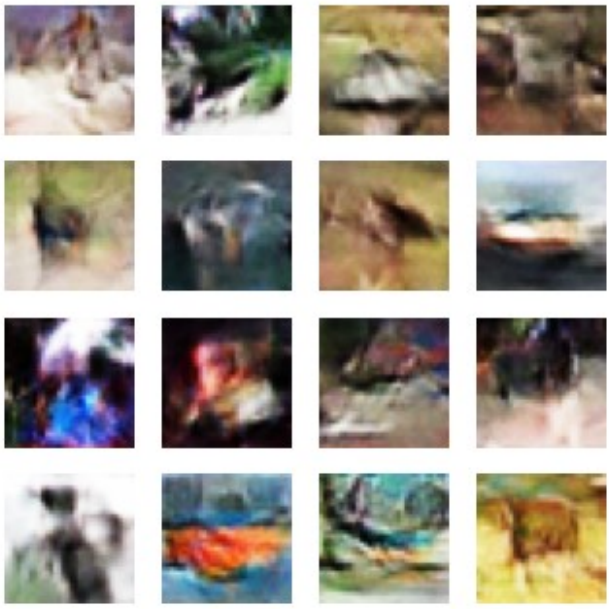

```
Epoch 84/100 - Generator Loss: 1.1126, Discriminator Loss: 1.2522 -
Time Taken: 156.61 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 85

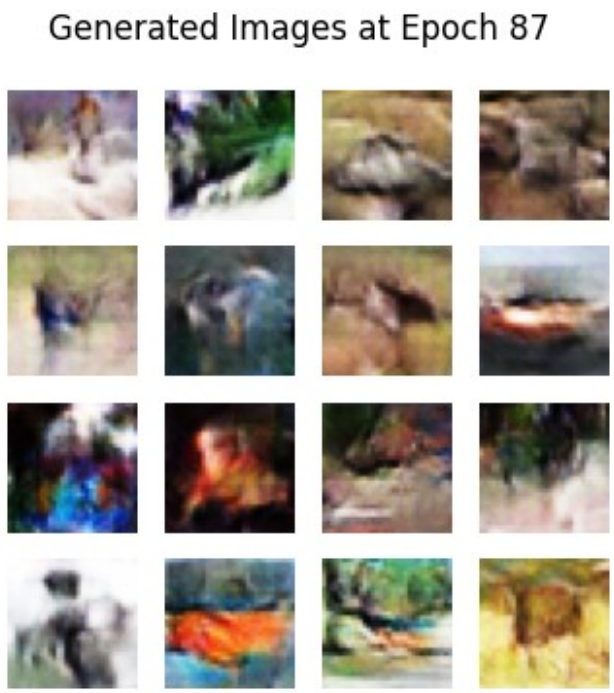


```
Epoch 85/100 - Generator Loss: 1.2485, Discriminator Loss: 0.8965 -
Time Taken: 156.30 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 86

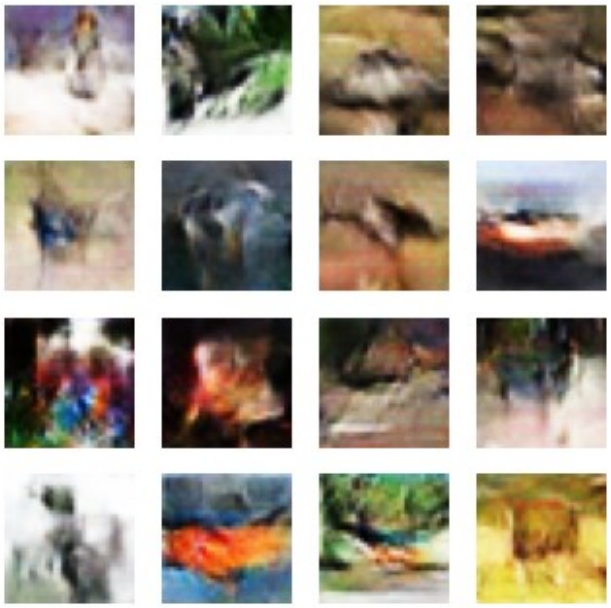


```
Epoch 86/100 - Generator Loss: 1.1019, Discriminator Loss: 1.3628 - Time Taken: 162.77 sec

<Figure size 640x480 with 0 Axes>
```



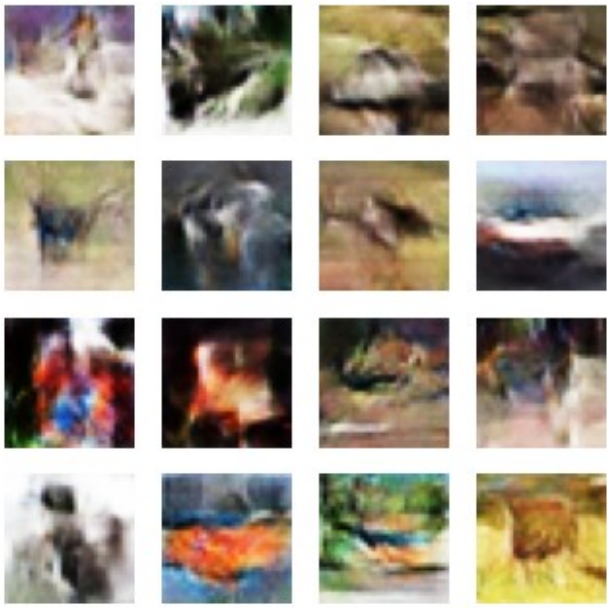

```
Epoch 87/100 - Generator Loss: 1.0935, Discriminator Loss: 1.3950 - Time Taken: 168.68 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 88

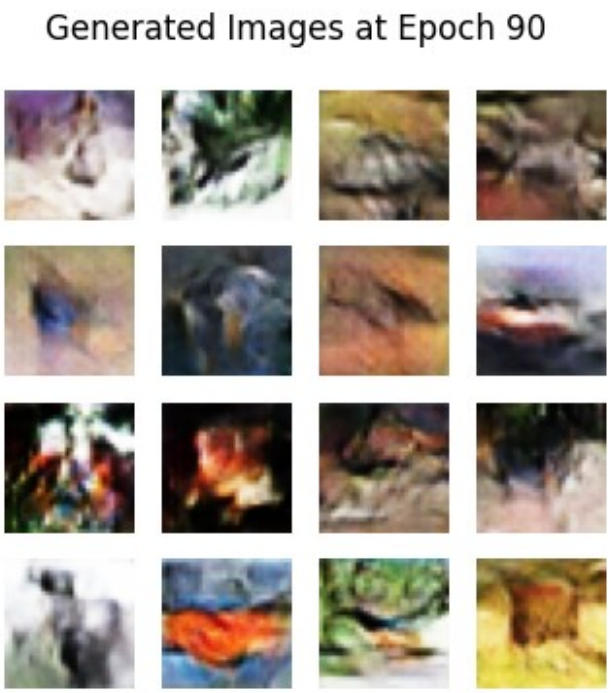


```
Epoch 88/100 - Generator Loss: 1.2551, Discriminator Loss: 0.8256 -
Time Taken: 161.82 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 89

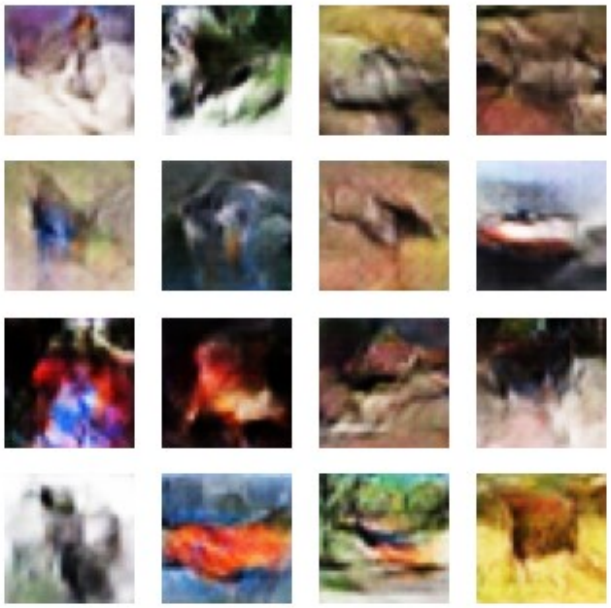


```
Epoch 89/100 - Generator Loss: 1.0529, Discriminator Loss: 1.2448 - Time Taken: 160.93 sec

<Figure size 640x480 with 0 Axes>
```



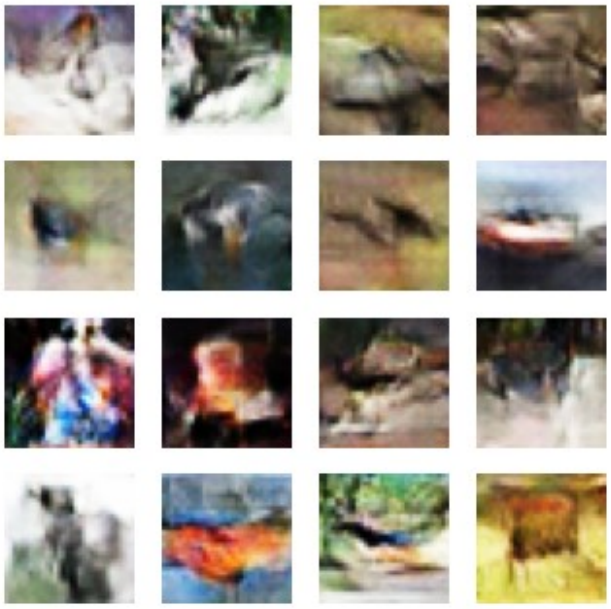

```
Epoch 90/100 - Generator Loss: 1.1724, Discriminator Loss: 1.3229 - Time Taken: 161.28 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 91

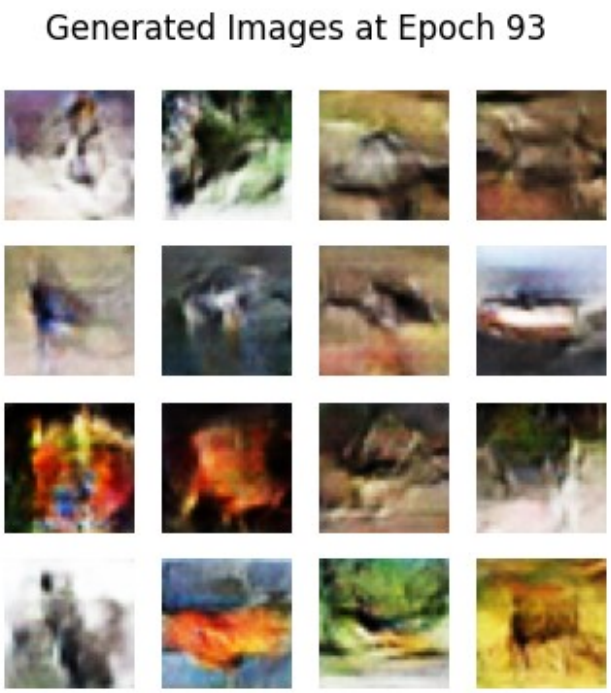


```
Epoch 91/100 - Generator Loss: 1.1050, Discriminator Loss: 1.0499 -
Time Taken: 161.49 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 92

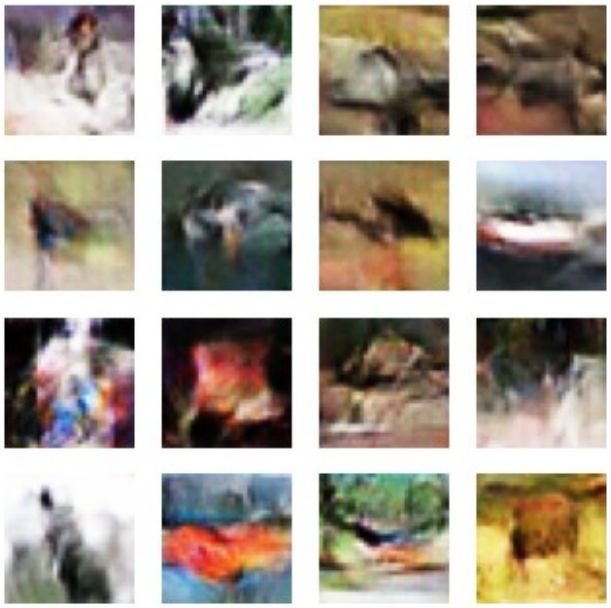


```
Epoch 92/100 - Generator Loss: 1.2284, Discriminator Loss: 1.0910 -
Time Taken: 160.66 sec

<Figure size 640x480 with 0 Axes>
```



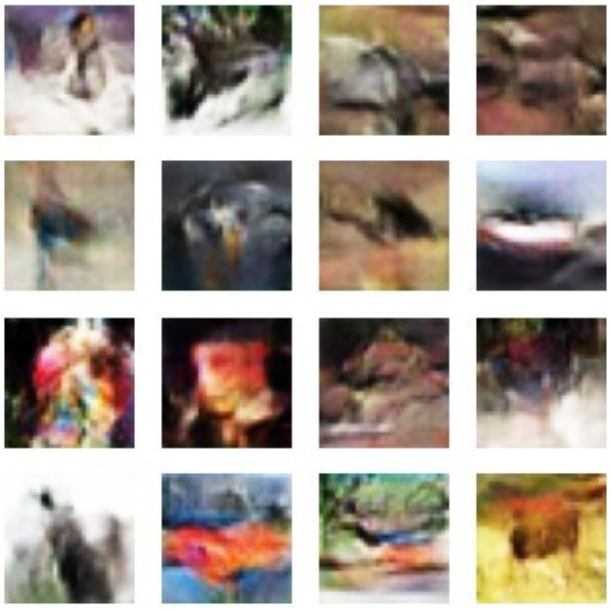

```
Epoch 93/100 - Generator Loss: 1.1708, Discriminator Loss: 0.9951 -
Time Taken: 161.95 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 94

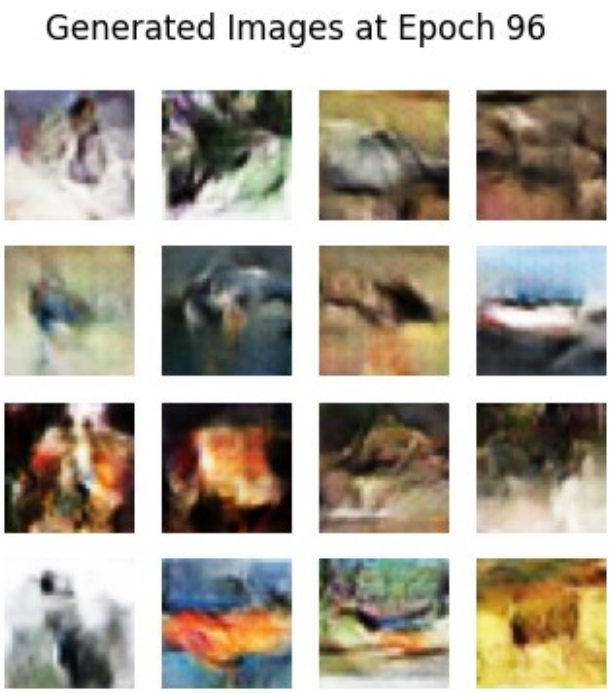


```
Epoch 94/100 - Generator Loss: 1.2667, Discriminator Loss: 1.2792 -
Time Taken: 160.46 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 95

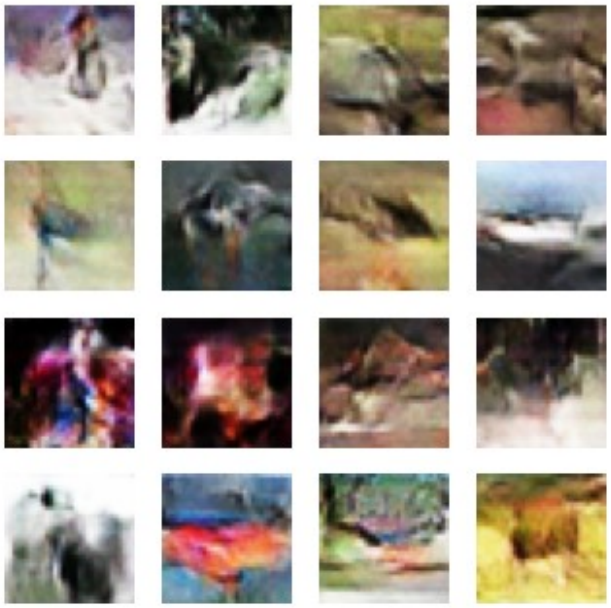


```
Epoch 95/100 - Generator Loss: 0.8980, Discriminator Loss: 1.1151 -
Time Taken: 160.98 sec

<Figure size 640x480 with 0 Axes>
```



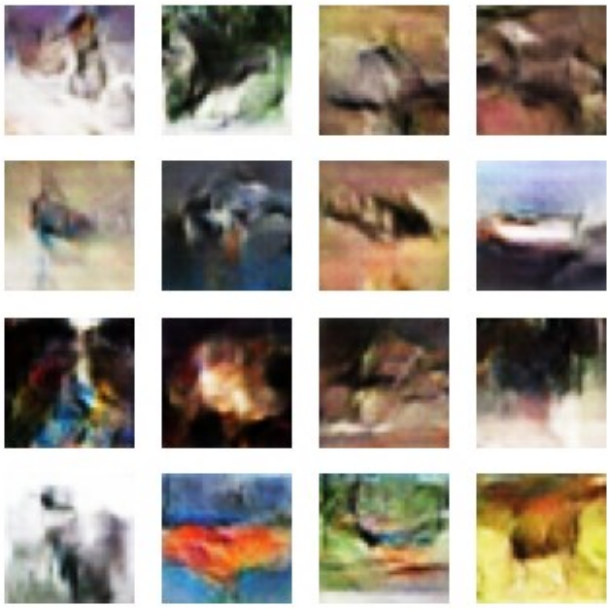

```
Epoch 96/100 - Generator Loss: 1.1504, Discriminator Loss: 1.2770 -
Time Taken: 161.73 sec

<Figure size 640x480 with 0 Axes>
```

Generated Images at Epoch 97

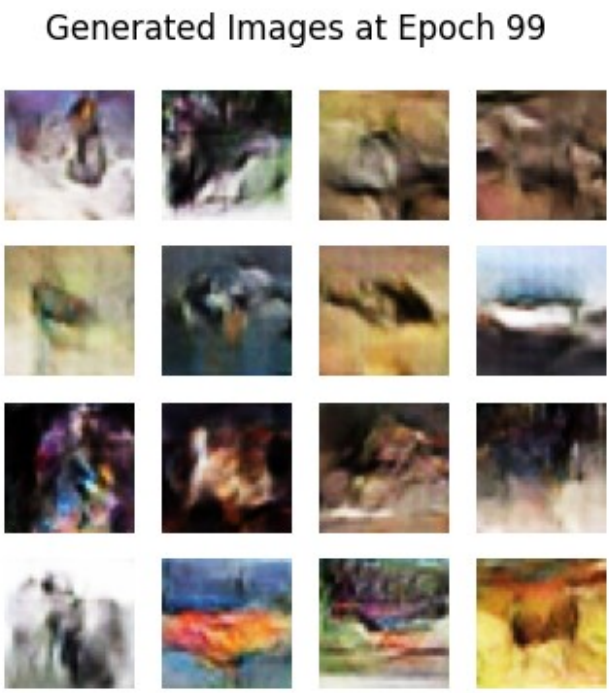


```
Epoch 97/100 - Generator Loss: 1.0856, Discriminator Loss: 1.1220 - Time Taken: 162.22 sec

<Figure size 640x480 with 0 Axes>
```

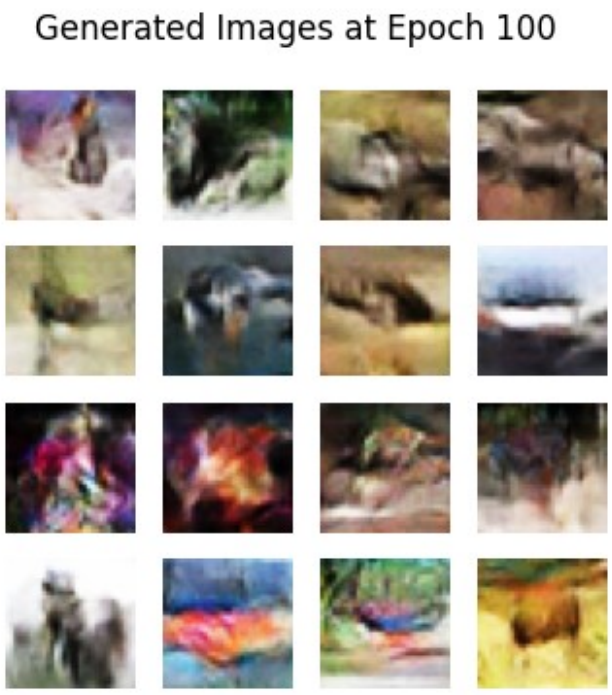
Generated Images at Epoch 98



```
Epoch 98/100 - Generator Loss: 1.1443, Discriminator Loss: 0.9166 -
Time Taken: 162.24 sec

<Figure size 640x480 with 0 Axes>
```




```
Epoch 99/100 - Generator Loss: 1.3180, Discriminator Loss: 1.0746 -
Time Taken: 162.00 sec

<Figure size 640x480 with 0 Axes>
```




```
Epoch 100/100 - Generator Loss: 0.9847, Discriminator Loss: 1.1212 - Time Taken: 161.69 sec

<Figure size 640x480 with 0 Axes>
```

```
# Save Models After Training
generator.save("cifar10_generator_2.h5")
discriminator.save("cifar10_discriminator_2.h5")
print("Training Complete and Models Saved!")
```

```
WARNING:tensorflow:Compiled the loaded model, but the compiled metrics have yet to be built. `model.compile_metrics` will be empty until you train or evaluate the model.
WARNING:tensorflow:Compiled the loaded model, but the compiled metrics have yet to be built. `model.compile_metrics` will be empty until you train or evaluate the model.
Training Complete and Models Saved!
```

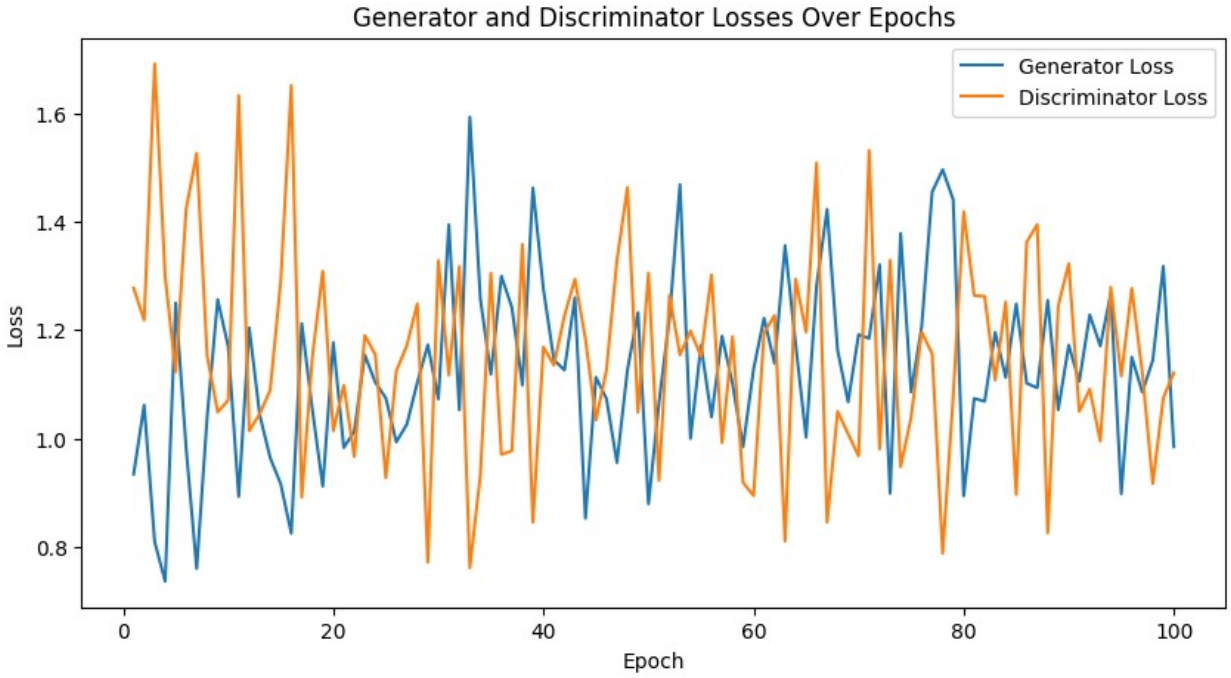
```
c:\Python311\Lib\site-packages\keras\src\engine\training.py:3103: UserWarning: You are saving your model as an HDF5 file via `model.save()`. This file format is considered legacy. We recommend using instead the native Keras format, e.g. `model.save('my_model.keras')`.
  saving_api.save_model(
```

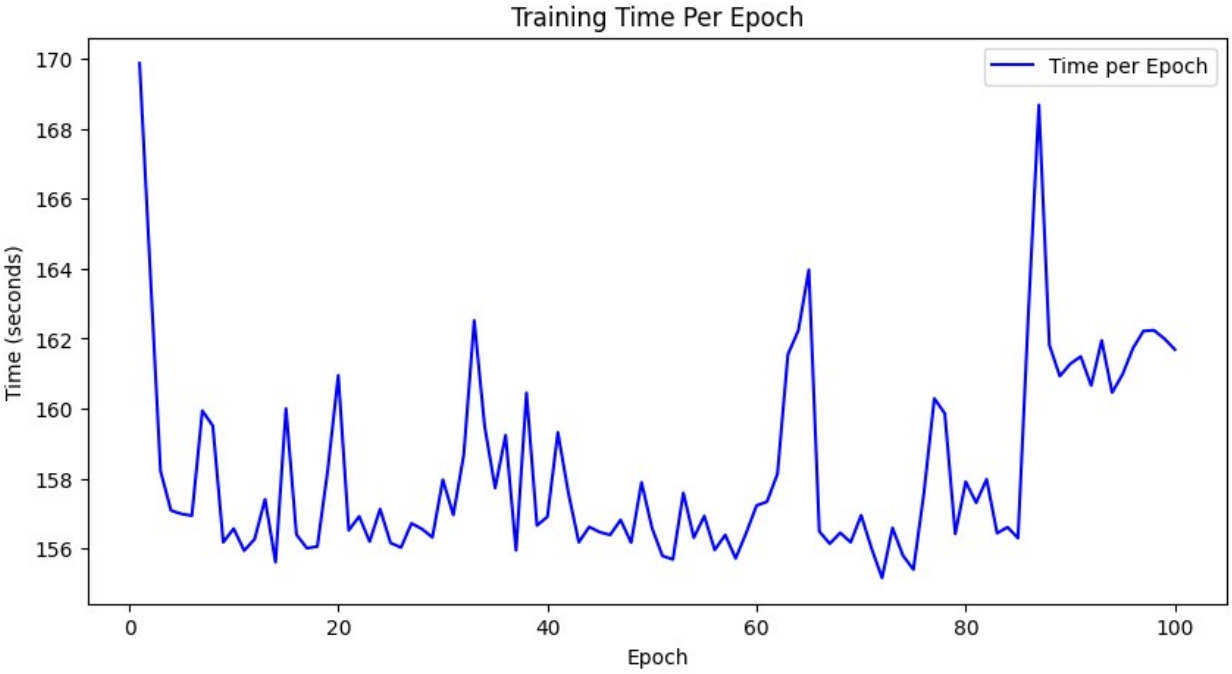
```
def plot_training_losses(gen_losses, disc_losses, epochs):
    plt.figure(figsize=(12, 6))
    plt.plot(epochs, gen_losses, label='Generator Loss', color='blue')
    plt.plot(epochs, disc_losses, label='Discriminator Loss',
```

```
color='red')
    plt.title('Training and Discriminator Losses Over Epochs')
    plt.xlabel('Epoch')
    plt.ylabel('Loss')
    plt.legend()
    plt.grid(True)
    plt.show()

# Generator and discriminator losses for each epoch
gen_losses = [
    0.9341, 1.0615, 0.8092, 0.7361, 1.2502, 0.9812, 0.7597, 1.0404,
1.2566, 1.1700,
    0.8928, 1.2045, 1.0434, 0.9640, 0.9160, 0.8248, 1.2123, 1.0547,
0.9116, 1.1773,
    0.9831, 1.0132, 1.1542, 1.1038, 1.0746, 0.9935, 1.0260, 1.1032,
1.1730, 1.0729,
    1.3947, 1.0527, 1.5937, 1.2580, 1.1185, 1.2999, 1.2421, 1.0985,
1.4627, 1.2762,
    1.1450, 1.1264, 1.2602, 0.8526, 1.1130, 1.0734, 0.9555, 1.1265,
1.2326, 0.8791,
    1.0660, 1.2222, 1.4689, 0.9999, 1.1720, 1.0397, 1.1892, 1.1008,
0.9843, 1.1277,
    1.2222, 1.1388, 1.3563, 1.1755, 1.0022, 1.2827, 1.4232, 1.1634,
1.0675, 1.1919,
    1.1848, 1.3209, 0.8987, 1.3787, 1.0859, 1.2058, 1.4552, 1.4965,
1.4413, 0.8938,
    1.0738, 1.0687, 1.1962, 1.1126, 1.2485, 1.1019, 1.0935, 1.2551,
1.0529, 1.1724,
    1.1050, 1.2284, 1.1708, 1.2667, 0.8980, 1.1504, 1.0856, 1.1443,
1.3180, 0.9847
]

disc_losses = [
    1.2777, 1.2185, 1.6920, 1.2987, 1.1228, 1.4240, 1.5265, 1.1523,
1.0486, 1.0708,
    1.6335, 1.0142, 1.0453, 1.0896, 1.2906, 1.6522, 0.8915, 1.1490,
1.3088, 1.0139,
    1.0983, 0.9665, 1.1903, 1.1550, 0.9275, 1.1247, 1.1715, 1.2488,
0.7714, 1.3286,
    1.1169, 1.3176, 0.7611, 0.9335, 1.3051, 0.9704, 0.9770, 1.3586,
0.8453, 1.1688,
    1.1354, 1.2262, 1.2943, 1.1841, 1.0342, 1.1260, 1.3291, 1.4634,
1.0481, 1.3052,
    0.9225, 1.2645, 1.1544, 1.1987, 1.1516, 1.3021, 0.9922, 1.1881,
0.9189, 0.8943,
    1.1953, 1.2270, 0.8103, 1.2944, 1.1964, 1.5088, 0.8453, 1.0500,
1.0085, 0.9675,
    1.5320, 0.9803, 1.3290, 0.9477, 1.0391, 1.1969, 1.1564, 0.7879,
1.0765, 1.4187,
    1.2642, 1.2624, 1.1078, 1.2522, 0.8965, 1.3628, 1.3950, 0.8256,
```

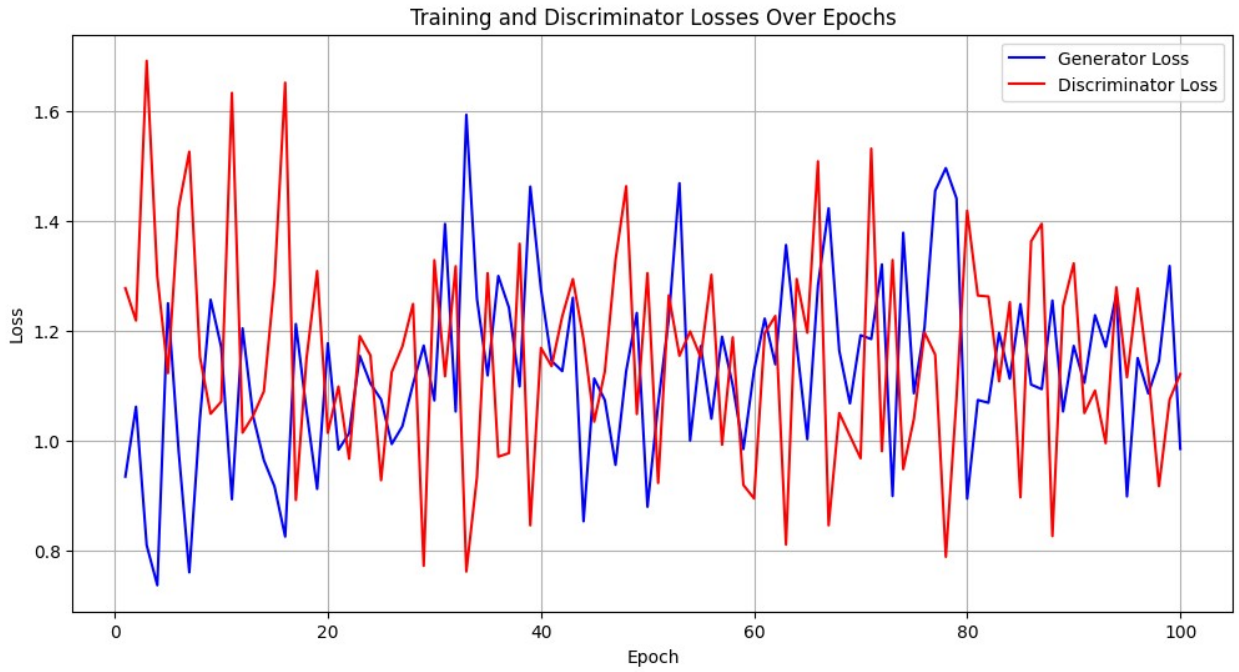
```
1.2448, 1.3229,
    1.0499, 1.0910, 0.9951, 1.2792, 1.1151, 1.2770, 1.1220, 0.9166,
1.0746, 1.1212
]

# Time taken for each epoch
times = [
    169.87, 164.02, 158.22, 157.09, 156.99, 156.94, 159.94, 159.51,
156.18, 156.57,
    155.94, 156.27, 157.41, 155.61, 160.00, 156.40, 156.01, 156.06,
158.26, 160.95,
    156.52, 156.92, 156.20, 157.13, 156.16, 156.03, 156.72, 156.56,
156.32, 157.97,
    156.96, 158.68, 162.52, 159.49, 157.73, 159.24, 155.95, 160.45,
156.66, 156.91,
    159.32, 157.60, 156.18, 156.62, 156.47, 156.39, 156.82, 156.17,
157.89, 156.59,
    155.79, 155.69, 157.59, 156.31, 156.93, 155.96, 156.39, 155.72,
156.44, 157.23,
    157.34, 158.14, 161.55, 162.24, 163.97, 156.49, 156.14, 156.45,
156.18, 156.95,
    156.00, 155.16, 156.59, 155.80, 155.40, 157.58, 160.29, 159.86,
156.42, 157.91,
    157.31, 157.98, 156.44, 156.61, 156.30, 162.77, 168.68, 161.82,
160.93, 161.28,
    161.49, 160.66, 161.95, 160.46, 160.98, 161.73, 162.22, 162.24,
162.00, 161.69
]

import matplotlib.pyplot as plt

epochs = range(1, 101)

# Plotting the losses
plt.figure(figsize=(10, 5))
plt.plot(epochs, gen_losses, label='Generator Loss')
plt.plot(epochs, disc_losses, label='Discriminator Loss')
plt.title('Generator and Discriminator Losses Over Epochs')
plt.xlabel('Epoch')
plt.ylabel('Loss')
plt.legend()
plt.show()

# Plotting the training times
plt.figure(figsize=(10, 5))
plt.plot(epochs, times, color='blue', label='Time per Epoch')
plt.title('Training Time Per Epoch')
plt.xlabel('Epoch')
plt.ylabel('Time (seconds)')
```

```
plt.legend()
plt.show()
```






```
epochs = list(range(1, 101))  # Epochs from 1 to 100

plot_training_losses(gen_losses, disc_losses, epochs)
```




```
import tensorflow as tf

# Load trained models
generator = tf.keras.models.load_model("cifar10_generator_2.h5")
discriminator =
tf.keras.models.load_model("cifar10_discriminator_2.h5")

print("□ Models loaded successfully!")
```

```
WARNING:tensorflow:From c:\Python311\Lib\site-packages\keras\src\
losses.py:2976: The name tf.losses.sparse_softmax_cross_entropy is
deprecated. Please use
tf.compat.v1.losses.sparse_softmax_cross_entropy instead.

WARNING:tensorflow:From c:\Python311\Lib\site-packages\keras\src\
backend.py:1398: The name tf.executing_eagerly_outside_functions is
deprecated. Please use
tf.compat.v1.executing_eagerly_outside_functions instead.

WARNING:tensorflow:From c:\Python311\Lib\site-packages\keras\src\
layers\normalization\batch_normalization.py:979: The name
tf.nn.fused_batch_norm is deprecated. Please use
tf.compat.v1.nn.fused_batch_norm instead.

WARNING:tensorflow:No training configuration found in the save file,
so the model was *not* compiled. Compile it manually.
WARNING:tensorflow:No training configuration found in the save file,
so the model was *not* compiled. Compile it manually.
□ Models loaded successfully!
```

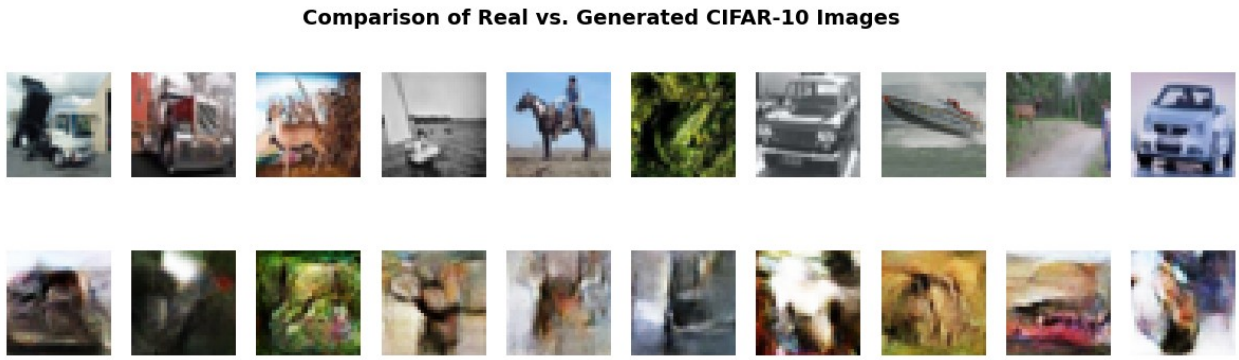
```
import numpy as np

# Generate 1000 fake images using the trained generator
noise = tf.random.normal([1000, 100])  # 1000 noise vectors
generated_images = generator(noise, training=False).numpy()

print("□ Generated images for evaluation!")
```

```
□ Generated images for evaluation!
```

```
import matplotlib.pyplot as plt
import tensorflow as tf
import numpy as np

# Load trained generator model
generator = tf.keras.models.load_model("cifar10_generator_2.h5")

# Load real CIFAR-10 dataset
(train_images, _), (_, _) = tf.keras.datasets.cifar10.load_data()
train_images = (train_images.astype("float32") - 127.5) / 127.5  #
Normalize to [-1,1]

# Generate fake images using the trained generator
num_images = 10  # Number of images to compare
noise = tf.random.normal([num_images, 100])  # Noise for generator
generated_images = generator(noise, training=False).numpy()

# Select random real images
real_images = train_images[np.random.choice(len(train_images),
num_images, replace=False)]

# Plot real vs. generated images side by side
fig, axes = plt.subplots(2, num_images, figsize=(15, 4))

for i in range(num_images):
    # Real Images
    axes[0, i].imshow((real_images[i] + 1) / 2)  # Normalize to [0,1]
for display
    axes[0, i].axis("off")

    # Generated Images
    axes[1, i].imshow((generated_images[i] + 1) / 2)  # Normalize to
[0,1] for display
    axes[1, i].axis("off")

# Titles for rows
axes[0, 0].set_ylabel("Real Images", fontsize=12, fontweight="bold")
axes[1, 0].set_ylabel("Generated Images", fontsize=12,
fontweight="bold")

plt.suptitle("Comparison of Real vs. Generated CIFAR-10 Images",
```

```
fontsize=14, fontweight="bold")
plt.show()
```

```
WARNING:tensorflow:No training configuration found in the save file,
so the model was *not* compiled. Compile it manually.
```




```
import matplotlib.pyplot as plt
import tensorflow as tf
import numpy as np

# Load trained generator model
generator = tf.keras.models.load_model("cifar10_generator_2.h5")

# Generate a large batch of images
num_samples = 64  # Generate 64 images to analyze diversity
noise = tf.random.normal([num_samples, 100])
generated_images = generator(noise, training=False).numpy()

# Plot generated images in a grid
fig, axes = plt.subplots(8, 8, figsize=(8, 8))

for i, ax in enumerate(axes.flat):
    ax.imshow((generated_images[i] + 1) / 2)  # Normalize to [0,1] for
display
    ax.axis("off")

plt.suptitle("Diversity in Generated CIFAR-10 Images", fontsize=14,
fontweight="bold")
plt.show()
```

```
WARNING:tensorflow:No training configuration found in the save file,
so the model was *not* compiled. Compile it manually.
```

Diversity in Generated CIFAR-10 Images